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ADENOMATOUS POLYPS OF THE SMALL INTESTINE

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WHEN one considers the frequency of adenomatous polyps in the large intestine, the incidence of this type of swelling in the small intestine is low. A search of the literature on this subject has shown that most writers have only described the pathology and symptoms associated with true adenomata arising from the intestinal mucosa. In addition to these benign neoplasms we have encountered polypoid conditions which, although on macroscopical examination appearing to be adenomata, were shown on microscopical investigation not to be so. The polypoid masses were not neoplasms which had become sessile or pedunculated.

CASE REPORTS

Case 1.—C. L. H., a married woman, aged 31 years, was admitted complaining of intermittent pains of a colicky type across the abdomen which had been present for six days. During this time she had vomited on several occasions, had not had a bowel action for five days, but thought that she had passed flatus the day before admission. On inquiring into her previous history, she said that on and off for years she had had acute attacks of pain across the abdomen, sometimes associated with vomiting. These attacks had lasted in some instances for several days, but had always disappeared without treatment. She had never passed any blood or mucus in the stools. Her family consisted of a girl of two years, who was healthy, and the patient believed that she was again about fourteen weeks pregnant.

ON EXAMINATION.—The patient looked well, but the tongue was dry. On the inner surface of each cheek were several pigmented areas but there was no pigmentation on the lips or tongue. Palpation of the abdomen revealed generalized tenderness across the upper abdomen, and an ill-defined mass was felt in the right hypochondrium. The fundus of the uterus was palpable about two fingerbreadths above the pubis. Rectal examination revealed nothing amiss. A definite diagnosis was not made, but in view of the pregnancy, and lack of evidence of small-bowel obstruction on the straight films of the abdomen, a policy of observation and fluid replacement was adopted. The next day her general condition was much improved, but the mass had disappeared from the right hypochondrium and a sausage-shaped tumour was now palpable in the left hypochondrium. The patient had also had some more pain. A diagnosis of intussusception was made.

AT OPERATION (May 12, 1951).—Midline epigastric incision. An intussusception of the small intestine was found at about the junction of its upper and middle thirds. This was easily reduced by 'milking' as far as the apex, but reduction of the last inch proved difficult because of a rounded mass in the intestine at the apex of the intussusception. The segment of bowel containing the unreduced portion was excised and an end-to-end anastomosis was done. On examination of the specimen after removal two pedunculated papillomata each about ¾ in. in diameter were found at the apex of the intussusception. A careful palpation of the rest of the small intestine revealed several soft tumours in the lumen which were assumed to be other papillomata; the largest of these was about ½ in. in diameter. There

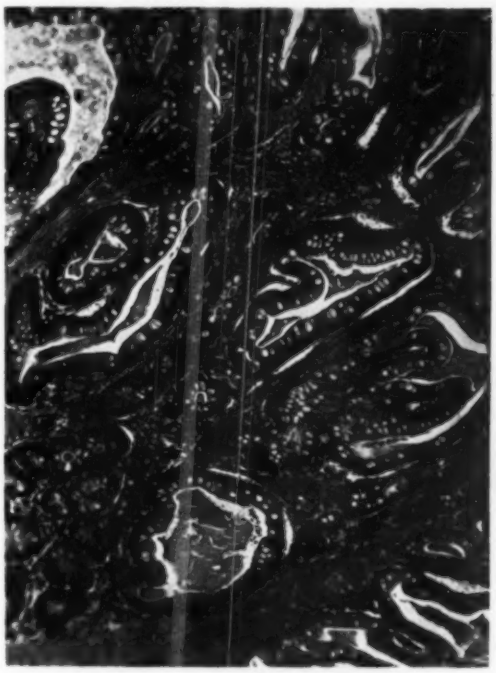

FIG. 599.—*Case* 1. Shows a mucus-secreting well-differentiated adenoma of the jejunum. (× 200.)

were no swellings palpable in the stomach or large intestine. The abdomen was closed.

The patient progressed satisfactorily, but had a miscarriage on the tenth day after operation. The fœtus, which was macerated, was unfortunately destroyed before we had an opportunity to dissect it. Following this the patient made an uninterrupted convalescence. A radiograph of the gastro-intestinal tract was carried out after she left hospital, but revealed no radiological evidence of papillomata in the bowel. The pathologist's report on the papillomata was: "Adenomatous papilloma of the small intestine. No evidence of malignancy." (*Fig.* 599.)

Case 2.—M. A., a female, aged 30 years, complained of pain in the right iliac fossa on and off for several years; there was nothing of importance in her past illnesses or personal history. The attacks of pain were

now becoming more frequent, occurring every few days, were burning in type, and caused nausea but no vomiting. The pain had no definite relationship to food. Her bowels were regular and she had no urinary symptoms or menstrual disturbances.

ON EXAMINATION.—The patient was pale and the tongue was clean and moist. On palpation of the abdomen there was tenderness on pressure in the right iliac fossa, and this was the only positive finding. Examination of the urine was negative. A straight radiograph of the abdomen and an intravenous pyelogram revealed no abnormality. A diagnosis of appendicitis was made.

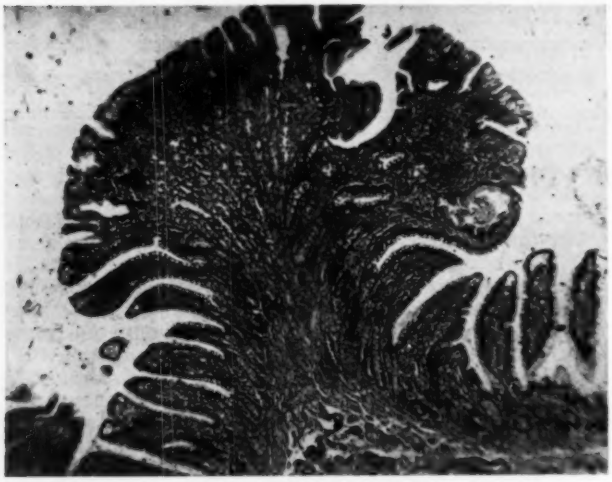

FIG. 600.—*Case* 2. A polyp of Meckel's diverticulum. Note the core which is formed by oxcyntic glandular epithelium. (× 45.)

FIG. 602.—Drawing of specimen from *Case* 3. It shows numerous polyps of the duodenum, as indicated by the arrows. The pyloric carcinoma is infiltrating all the coats of the stomach.

AT OPERATION (Jan. 10, 1952).—Muscle-splitting incision. The appendix did not appear to be diseased and the cæcum and ileocæcal angle were normal. No abnormality was detected in the right side of the pelvis. A Meckel's diverticulum was found but did not appear to be inflamed or diseased. The appendix and the Meckel's diverticulum were removed and the abdomen was closed.

The patient made an uninterrupted recovery and has been free of symptoms since. Dissection of the appendix post-operatively showed no abnormality and the pathologist reported that there was no evidence of any inflammation. The Meckel's diverticulum contained two papillomata, one about $\frac{1}{4}$ in. in diameter and the other about $\frac{3}{16}$ in. in diameter; both had narrow stalks. The pathological report on these papillomata was: "Polyp covered by intestinal epithelium and showing some round-celled infiltration in the submucous areas." (*Fig.* 600.) "There is no true stroma but a pseudostroma consisting of oxcyntic cells similar to those normally found in the stomach." (*Fig.* 601.)

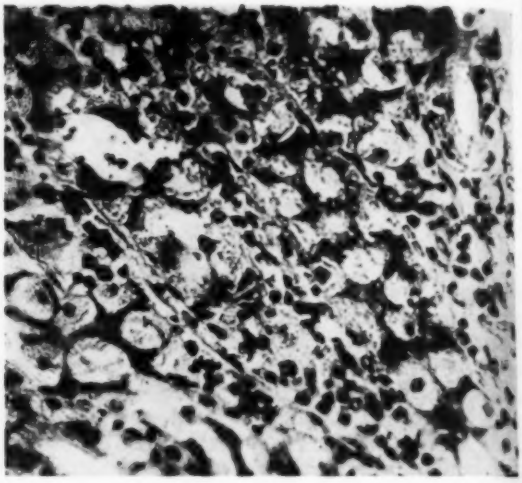

FIG. 601.—*Case* 2. Photograph of the oxcyntic epithelium of the polyp shown in *Fig.* 600. (× 335.)

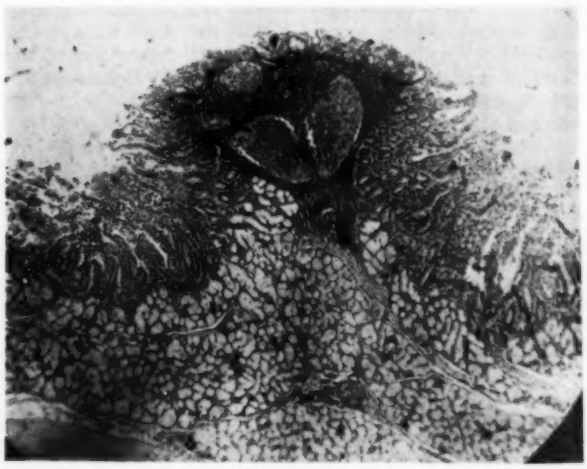

FIG. 603.—*Case* 3. Polyp of the duodenum due to an adenomatous hyperplasia of Brunner's glands and to a reactive lymphocytic hyperplasia with germ follicle formation (Flemming's centres). (× 45.)

Case 3.—T. A. F., a male, aged 45 years, was admitted complaining of vomiting on and off for two years. There was nothing of importance in his past illnesses or personal history, except that he was a rather heavy smoker. About two years ago he began to vomit, especially in the morning, and the material vomited was generally greenish fluid. Gradually he developed an uncomfortable feeling in the epigastrium and suffered with flatulent dyspepsia. He had lost 2 st. in weight in the last two years, but had no other symptoms.

On Examination.—The patient was found to have lost a lot of weight. On palpation of the abdomen a large irregular mass was felt in the epigastrium. A diagnosis of carcinoma of the stomach was made, and this was confirmed by a radiograph, which showed an extensive filling defect occupying the body and pyloric end of the stomach. After careful pre-operative preparation, laparotomy was decided upon.

At Operation (Jan. 15, 1952).—Midline epigastric incision. A large mobile carcinoma was found occupying the body and pyloric end of the stomach. A partial gastrectomy was done, removing the great omentum and the glands along the lesser curve. An antecolic loop of jejunum was used for the anastomosis, with the formation of a valve. On section of the duodenum several polypoid masses were noted, varying in size from ¼ in. to ½ in. in diameter; they were pink in colour and sessile. After removing the specimen, the same types of swelling were noted in the part of the duodenum which was removed (*Fig.* 602).

Following the operation the patient improved for a while, but then developed an intractable diarrhœa and despite every effort to improve his condition, went downhill and died. A post-mortem examination was refused.

The swelling of the stomach was an adenocarcinoma, and the swellings in the duodenum were due to an adenomatosis of Brunner's glands, with the mucosa overlying them showing reactive hyperplasia (*Fig.* 603).

Case 4.—W. A. J., a male, aged 45 years, came to hospital complaining of epigastric pain for several months. His pain bore no relationship to food, was continuous, and was eased by vomiting; his appetite was poor and there was marked loss of weight.

On Examination.—The patient was found to be very thin and pale. On palpation of the abdomen no mass was discovered and the rest of the examination was negative. A barium meal showed a filling defect occupying the pyloric end of the stomach, which was almost certainly a carcinoma. Following pre-operative preparation a laparotomy was arranged.

At Operation (April 8, 1952).—Midline epigastric incision. A large carcinoma of the pylorus and body of the stomach was found. There were no palpable secondary deposits in the liver, but there were many enlarged glands along the lesser curve. The growth, together with the great omentum and the glands along the lesser curve, was resected and a partial gastrectomy was done. On section of the duodenum several small polyps were noted on the mucous membrane; these measured about 2 mm. in diameter and appeared to be on slender stalks.

The patient made a smooth convalescence and is now progressing satisfactorily.

The pathological report of the ulcer of the stomach showed it to be a carcinoma, and the small polyps in the duodenum were reported as being due to adenomatosis of Brunner's glands, with the mucous membrane showing some epithelial hyperplasia and round-celled infiltration. These histological features were identical with those of *Case* 3 illustrated by *Fig.* 603.

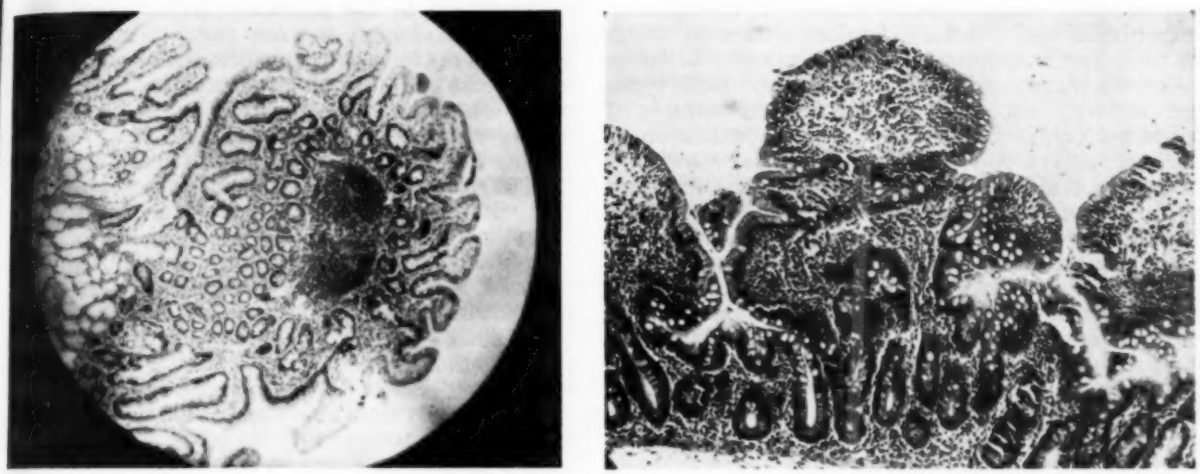

Fig. 604.—*Case* 5. Polyp of the jejunum due to reactive adenomatous and lymphoid hyperplasia.

Case 5.—B. G., a female, aged 42 years, complained for several weeks of upper abdominal discomfort and nausea. As regards her past illnesses she was treated in 1946 for a macrocytic anæmia, and previous to this had had tuberculosis of the lungs, which was now quiescent. In 1951 she was operated upon for tuberculous salpingitis.

On Examination.—The patient was found to be thin and anæmic. No mass was palpable in the abdomen, but a radiograph of the gastro-intestinal tract showed a filling defect at the pyloric end of the stomach, with some delay in emptying.

At Operation (Dec. 18, 1951).—Midline epigastric incision. A carcinomatous mass was found at the pylorus. A partial gastrectomy with an antecolic loop was done, and on opening the jejunum to make the stoma about 5 in. from the duodenojejunal flexure, the mucous membrane was seen to be studded with small polypoid masses on slender stalks measuring from 1 to 2 mm. in diameter; these on section were shown to be areas of reactive hyperplasia (*Fig.* 604). The ulcer of the stomach was a carcinoma.

DISCUSSION

Whilst fully realizing that in some instances the polyps which have been described are only of pathological interest, in others they are associated with definite symptoms producing recognizable clinical syndromes. In view of our findings the following

classification of these polypoid conditions of the small intestine is suggested :—

1. True adenomatous polyps of the intestinal mucosa :—

a. Those associated with pigmentation of the lips and cheeks and having certain familial tendencies.

b. Those not associated with pigmentation.

2. Polyps formed by heterotopic tissue.

3. Reactive hyperplasia of the mucous membrane, glandular tissues, and lymphoid tissues macroscopically simulating a true adenoma.

The true polypoid adenomata can be divided into two very distinct subsections, not because the pathology of the adenomata differ, but because in the one instance there is pigmentation of the mucous membranes and a definite familial tendency, whilst in the other no pigmentation is found and as far as is known there is no hereditary factor. Both types are distinctly uncommon. *Case* 1 is an example of intestinal polyposis associated with pigmentation of the lips and oral mucous membranes, and sometimes of the face and digits. In our case there was no evidence of pigmentation in these latter sites. Hutchinson (1896) drew attention to pigmentation occurring on the lips and mucous membrane of the mouth in twins, and Parkes Weber (1919) reported that one of the twins described by Hutchinson had died of intussusception. Jeghers, McKusick, and Katz (1949), in a comprehensive review of the literature, drew attention to this rare familial disorder and reported 10 cases of the syndrome. The reader is referred to these articles for a full and excellent account. Wolff (1952), in reporting a further case, found 26 other acceptable instances of the condition apart from his own. Our case showed the typical areas of brown pigmentation of the mucous membrane inside the cheek. This patient's daughter, aged 2 years, had pigmented spots on the lips, but had no other pigmented patches and never had any intestinal troubles. The syndrome is one of pigmentation, multiple intestinal polypi, and a familial tendency. The pigmentation occurs in early childhood on the mucous membrane of the mouth, and on the lips, but rarely on the tongue. Pigmentation may also occur on the fingers and toes. The patches in the mouth are prominent and persist, but those on the lips, face, and digits may fade. Papillomata may occur in the stomach and small and large intestines ; such a case was the one reported by Tanner (1951), but in all reported instances the small intestine has been involved, even when nothing amiss was found in the stomach and large bowel. Complete records of a sufficient number of cases have not been published to define exactly the familial incidence, and no genealogical tables are large enough to reach a conclusion regarding the genetic mechanism. It appears to be a distinct clinical entity and unrelated to colonic polyposis ; in fact the finding of polypi in the small intestine is unknown in association with typical familial polyposis coli. The symptoms arising from adenomata of the small bowel are intestinal hæmorrhage and abdominal pain due to intussusception. The syndrome is important because of the ability to make a diagnosis if the pigmented areas are recognized. The papillomata are typical intestinal adenomata arising from the mucosa, and show the increase in goblet cells so characteristic of adenomata of the intestinal tract (*Fig.* 599). There is a tendency for them to become malignant (Foster, 1944).

We have no example of a papilloma occurring without the pigmentation syndrome. In reviewing the literature one finds that Olson, Dockerty, and Gray (1951) collected the material from the surgical and pathological departments at the Mayo Clinic for the years 1911–42, and found only 22 instances of adenomata of the small intestine, and out of these only 11 gave rise to symptoms during life. Saint (1927), in a review of the subject, had only 1 case of his own to report. The tumours are most frequent in the duodenum, less frequent in the ileum, and rarely found in the jejunum. Finney and Finney (1931) noticed in their cases that other pathological lesions were common in the intestinal tract, especially carcinoma, and that when adenomata were present in the duodenum they gave rise to symptoms which closely simulated duodenal ulcer. Just as in the syndrome with pigmentation, adenomata may occur both in the stomach and in the large bowel in association with those in the small intestine, and Ravitch (1948) described 2 such cases. Haggard and Floyd (1935) noted several cases of adenomata of the small intestine in members of the same family, and thought the condition might be familial. This, however, could not be proved, and there is no mention of any pigmentation in these cases. As far as records go there is no evidence that adenomata of the small intestine, apart from those associated with pigmentation of the mucous membrane of the mouth and lips, have a familial tendency.

A polyp containing heterotopic tissue is exemplified by *Case* 2. At first sight this polyp appeared to have a fibrous stroma, but on closer examination it was discovered that a pseudo-stroma was present consisting of oxcyntic cells. Heterotopic tissue is not infrequently found in the small intestine, more especially in the duodenum and in a Meckel's diverticulum ; it may appear in the form of a polyp.

It is not our intention to discuss the various theories as to why heterotopic tissue occurs, but rather to stress the clinical importance of gastric mucosa in heterotopic sites in the small intestine. Of all tissues, gastric mucosa, more so than pancreatic or other varieties, is the most likely to produce symptoms. It is generally believed that erosion of the mucous membrane due to acid secretions must occur before symptoms can arise ; but the erosion may not necessarily take place at the site of the heterotopic tissue. The ulceration may occur in the small intestine near the base of the Meckel's diverticulum, when the diverticulum is the site of the heterotopic mucosa ; such was the case described by Greenblatt, Pund, and Chaney (1936). It may be, therefore, that the removal of the acid-secreting tissue will relieve the symptoms even though the mucous membrane in the specimen is intact. In these cases pain of some sort is usually present, and may be of the typical food-pain cycle comparable to that found in duodenal ulcer. It is supposed that the same factors that stimulate peptic secretion also stimulate the heterotopic cells. In other patients the pain bears no definite relationship to food, as was exemplified in our *Case* 2. It is suggested that a Meckel's diverticulum, a common site for heterotopic tissue,

especially acid-secreting cells, should be searched for and removed when it is found, especially when a satisfactory cause for the patient's symptoms is not discovered. In *Case* 2 there was no evidence either macroscopically or microscopically that the appendix was at fault, and as the patient's symptoms have been completely relieved, we have assumed that the polyps containing the oxcyntic cells in the Meckel's diverticulum were the cause of the symptoms.

In the remaining three cases, although the polyps appeared at first sight to be true adenomata, they were in actual fact due to a reactive hyperplasia of the mucous membrane. Saint (1927), in his account of intestinal polyps, said that the commonest type is due to glandular hyperplasia, and of his 9 cases 8 occurred in the ileum and 1 in the jejunum. They appeared as multiple excrescences on an average about 1 mm. in diameter and were very similar to those found in our *Case* 5. These polyps may be sessile or pedunculated and occur on the crest of the valvulæ conniventes. The same author described the microscopical picture as a rising up of the mucous membrane and submucosa above the general level of the lumen of the intestine, and the condition to be one of local hyperplasia. In a few instances he found the pedicle to be formed by a mass of lymphoid tissue and in other cases there was a fine connective-tissue stroma with a few thin-walled capillaries. This corresponds with the picture seen in *Fig.* 604. Ordinarily the lymphoid follicles in the intestinal mucosa do not project into the lumen to any degree, and part of the polypoid mass is due to hyperplasia of the lymphoid tissue as well as of the mucous membrane.

In the other two cases the polyps were due to a reactive hyperplasia, mainly of Brunner's glands, in the wall of the duodenum, which had so projected into the lumen as to lift up the mucous membrane, which likewise showed hyperplastic changes. Saint (1927) did not refer to this type in his article.

In each of these three cases showing reactive hyperplasia a carcinoma of the stomach was present and one must assume the conditions are in some way related. In *Cases* 3 and 4 the duodenum was the site of the hyperplasia, but in *Case* 5 the duodenum appeared normal, and it was the jejunum, about 5 in. beyond the duodenojejunal flexure, that was the part of the bowel affected.

Although these hyperplastic polyps occurred in association with gastric carcinomata, they were not due to any neoplastic infiltrative activity. It is thought that the stimulus for hyperplasia was a reaction to the infection which accompanied the carcinomata.

SUMMARY

Several varieties of polyps of the small intestine have been described, a classification suggested, and the importance from the surgical point of view of some of these types is related.

In conclusion we are indebted to Dr. Winston Evans for the photomicrographs and to Miss Duckworth, of the Department of Surgery, University of Liverpool, for the coloured drawing.

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CASTS OF THE CEREBRAL VENTRICLES

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THE method of studying anatomical cavities by means of casts is an old one, but it does not appear to have been applied very widely to the cerebral ventricles. Leonardo da Vinci (1452–1519) was the first to make a cast of the cerebral ventricles. After making escape holes in the lateral ventricles he injected molten wax into the fourth ventricle with a syringe, and recorded his observations with drawings and notes. While his conception of the form of the ventricles was not very accurate his work was of very high standard considering the technical difficulties inseparable from the making of such casts in unfixed brains. The next illustration of a ventricular cast was published by Welcker (1878), though he refers in his paper to a cast previously made by Rauber which he had seen in the Leipzig Museum. Welcker used beeswax for his injection material, and he recorded the technique of his method, which included the incorporation of wires for support. The illustration shows that the cast was faulty and distorted, yet it was reproduced in several continental text-books and the tenth edition of *Quain's Anatomy* (1893).

In 1900 Retzius gave an account of the practical details and difficulties met with in preparing casts; he used Wood's metal as the injection material. His casts were much more accurate than those of Welcker, and his beautiful lithographic illustrations are still to this day copied in most standard text-books of anatomy (Buchanan, 1949; Cunningham, 1951; *Gray's Anatomy*, 1950; and many others). Dandy (1918) first showed that the ventricles when filled with air could be outlined in X-ray photographs,

since when exact knowledge of ventricular anatomy has been necessary to both the radiologist and the neurosurgeon, and the preparation of accurate ventricular casts assumes a practical importance transcending its former purely academic interest.

Locke (1926) injected celloidin through trephine holes in fresh cadavers and macerated the complete head away from the cast with hydrochloric acid, and after fifteen attempts he obtained six casts that were good enough to study, though he admitted that even these were very poor. Torkildsen and Penfield, as late as 1933, wrote, " the normal anatomy of the ventricles is not well known ". Torkildsen (1934, a, b), reported on 11 casts in paraffin wax, and compared their dimensions with 13 radiographs selected from 450 normal ventriculograms and encephalograms. He detailed the technique of injection with paraffin wax, and made a brass model of a cast selected as typical. Twining (1939) recommended making ventricular casts from post-mortem material in cases of tumour, and he illustrated such a cast, but made no mention of the injection material used or the technique of injection. Robertson (1941) illustrated a celloidin cast of a lateral ventricle but made only passing reference to it in his monograph. Cairns and Jupe (1951) wrote that, " in interpretation of anteroposterior and postero-anterior projections a model is helpful ", and they illustrated a photograph of such a model after Retzius.

Since the ventricles vary considerably in form they cannot be represented satisfactorily by a single model ; a series of casts is necessary, and these must reproduce accurately the shape of the living ventricles. It was decided that injection into the ventricles through trephine holes in the skull, using unfixed material, was not only impracticable but would for various technical reasons be likely to give imperfect and distorted casts, as Locke (1926) had found.

Having decided, like Retzius (1900) and Torkildsen (1934, a, b) before us, that satisfactory casts can be made only from hardened brains, we were confronted with the three main problems inseparable from the making of ventricular casts. The first is to avoid distortion of the ventricles during fixation of the brain. The second is to find a substance sufficiently fluid to run into narrow crevices yet strong enough when solid to support the weight of the lateral ventricles at the interventricular foramina and the weight of the fourth ventricle on the stalk of the aqueduct ; while the third problem is to ensure that a complete cast is made.

MATERIAL AND METHODS

Casts of the ventricles of 24 adult and 5 fœtal brains have been made. The evidence that the brains were normal rests on two points : First, the adult material was obtained at random from autopsies in which the pathologists had no wish to examine the brain, a fact which emphasizes the presumptive normality of the intracranial contents. Secondly, no unusual features were found in any of the specimens during the careful removal of the brain substance from around the casts. It was found that Marco resin 26 C, which one of us (D. H. T.) had used for developing a method of making bronchopulmonary casts, is very suitable for making ventricular casts. Its shrinkage during hardening is of the order of only 1 per cent.

A detailed account of the technique employed is given in *Appendix A*. Briefly, the following operations are carried out. The brain is removed from the cranium with great care and immediately suspended by the proximal part of the basilar artery in 10 per cent formalin, in which it is totally immersed. The adjacent membranes should be freed from the optic chiasma before the brain is suspended ; otherwise the optic chiasma may be displaced posteriorly. The brain is not laid on any hard surface, even momentarily, before being placed in formalin, for fear of producing permanent distortion.

After fourteen days the fixing fluid is renewed and the brain left therein for a further four weeks for complete hardening before the injection is made. To prevent distortion during the injection the hardened brain is submerged in water, where it remains until the injected resin is quite hard. To ensure that the cast is complete the brain tissue is removed from it in careful slices, to observe if any cavity is not completely filled, and if necessary to complete the cast by running in additional resin before the adjacent brain tissue is removed.

The amount of shrinkage of the brain during fixation in formalin has been investigated. Measurements were made of ten brains immediately after suspension in 10 per cent formalin, and were repeated after one, four, and six weeks. It was found that after one week the average linear shrinkage was well under 2 per cent (*Table I*) and that no subsequent shrinkage occurred. Torkildsen (1934, a, b) inferred similar results by comparing the average dimensions of his casts with those of ventriculograms. From this it is apparent that fixation does not appreciably alter the size or shape of the ventricles.

Table I.—MEASUREMENT OF SHRINKAGE OF BRAINS IN 10 PER CENT FORMALIN

No. of Brain	Length		Breadth	
	Fresh	After 1 week	Fresh	After 1 week
	cm.	cm.	cm.	cm.
1	18·0	18·0	15·0	15·0
2	16·5	16·3	12·5	12·5
3	18·0	17·5	14·0	13·8
4	18·5	17·8	15·0	14·3
5	17·0	16·7	13·5	13·3
6	18·0	17·8	13·5	13·5
7	18·0	17·9	13·8	13·6
8	16·5	16·5	14·0	13·5
9	17·2	17·0	15·0	15·0
10	16·0	15·9	14·0	13·7
Average shrinkage	1·2 per cent		1·5 per cent	

(These brains are not those used for the casts, and the numbers do not correspond to those in *Tables II-VII.*)

A further factor requires consideration. Although the fixed brain is hard, the roof and floor of the third ventricle are delicate. It is therefore impossible to exert sufficient pressure to cause distension of the ventricles while the injection is being made, as comparatively slight pressure ruptures the roof or floor of the third ventricle. This would be less the case with Wood's metal, which solidifies at escape

holes and at its edges while the central mass remains molten and subject to pressure from an injecting syringe. Marco resin gels in the opposite order, solidification commencing at the centre of the mass and being delayed peripherally in slender streams of fluid resin, especially if they are in contact with water. The lateral recess of the fourth ventricle is not always well filled, even by Wood's metal, when the injection is made into the lateral ventricle (Retzius, 1900), and to obtain a good cast of the lateral recess and foramen of Luschka it is advisable to inject Marco resin directly into the fourth ventricle.

In most of the casts made by this method it was found that in the temporal horns much of the upper and lower ependyma was in contact with the choroid plexus, so that the cast did not indicate the full extent of the cavity that would be opened up if the ependyma were pushed slightly apart. In a living or an unfixed brain a very slight intraventricular pressure should be sufficient to do this, and study of ventriculograms shows that air does, in fact, frequently do so. It thus appears that resin casts of the ventricles made from the hardened brain are very slightly thinner than air ventriculograms, but this difference is quite negligible in proportion to the great variation in size of normal ventricles.

All the adult and fœtal casts referred to in this paper are preserved in the Museum of the Royal College of Surgeons of England and are available for inspection by those interested.

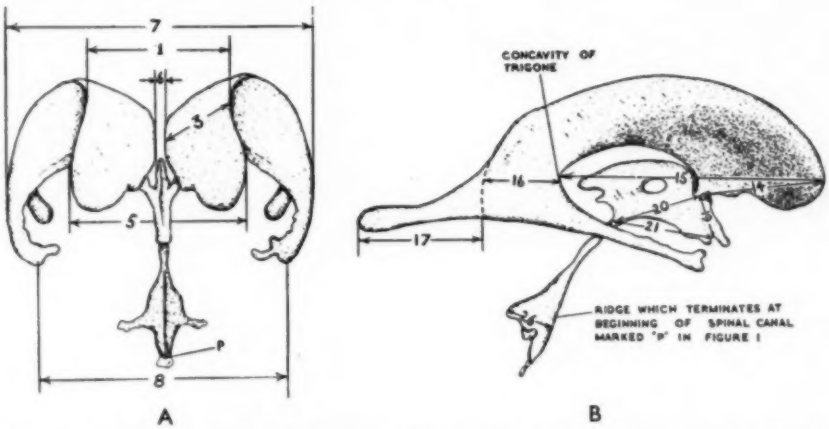

FIG. 605.—A, Anterior view of cast to illustrate meaning of 'spread'. Numbers refer to measurements. B, Lateral view of cast to show how various measurements were made.

FINDINGS

The observations made on the casts are here recorded under two headings: (1) measurements of size; and (2) anatomical features displayed by the casts.

MEASUREMENTS

The volume of the brains was measured by the volume of water they displaced, and that of the casts by weighing them and calculating their volume from the specific gravity of the resin, which was found to be 1·29. This method for the casts gives very accurate figures.

In making measurements of the casts we were guided by two principles: (1) as far as possible to make measurements which could also be made directly from sagittal and lateral pneumograms; and (2) to select for measurement fixed points that do not vary according to the judgement of the individual worker. Consequently while most of our measurements conform with those of other workers on pneumograms, in a few cases we have chosen different points. We have avoided, for example, such vague positions as the middle of the trigone. Certain points difficult to describe are indicated in *Fig.* 605.

Torkildsen and Pirie (1934) wrote: "The anteroposterior films more than any others give the most valuable information about the size, form, and position of the ventricles." They divided the lateral pneumogram (and the lateral surface of their model) into six parts, which can be identified in anteroposterior and postero-anterior views; but they did not give the normal anteroposterior dimensions of these six parts. Torkildsen (1934, a, b) in two papers referred to the six parts and their interpretation in anteroposterior projections, but in neither paper did he give any indication of their normal measurements and variations.

The following is a list of the measurements of the casts which have been recorded in *Tables II–VII*, with the average figures in centimetres alongside each. Where available, measurements of the ventricles given by other workers are quoted for comparison.

Measurements made in Anteroposterior View.—

Lateral Ventricles.—

Bodies:—

1. Minimum spread of bodies (i.e., shortest distance between lateral edge of bodies, *see Fig.* 605 A)	3·0 cm.
2. Angle between roofs	126°
3. Minimum oblique width of body (*see Fig.* 605 A) (1·6–2·0 cm., Orley, 1949; 1·5–2·6 cm., Robertson, 1941)	1·5 cm.
4. Minimum thickness of body	0·6 cm.

Anterior horns:—

5. Maximum spread of tips (*Fig.* 605 A)	3·3 cm.

6. Minimum width of septum lucidum, *see Fig.* 605 A (0·2–0·3 cm., Orley; Davidoff and Dyke, 1951; 0·3 cm., Robertson) 0·14 cm.

Temporal horns :—

7. Maximum spread of convexities (*Fig.* 605 A) 7·3 cm.
8. Spread of tips (*Fig.* 605 A). The tip of the horn is not clearly defined, and this measurement is of doubtful value 5·7 cm.

Third Ventricle.—

9. Height in silhouette (more than 2·0 cm., Orley; Davidoff and Dyke; 2·5–3·0 cm., Cairns and Jupe, 1951) 2·2 cm.
10. Maximum width (0·2–0·8 cm., Orley; Davidoff and Dyke; 0·3–0·9 cm., Robertson) 0·55 cm.

Aqueduct.—

11. Minimum width (0·2 cm., Cairns and Jupe) 0·15 cm.

Fourth Ventricle.—

12. Width of floor (1·3–2·0 cm., Robertson) 1·7 cm.

Measurements made in Lateral View.—

Lateral Ventricles.—

Bodies :—

13. Length of body from centre of interventricular foramen to concavity of trigone (5·0 cm., Orley; Davidoff and Dyke) 4·0 cm.

Anterior horns :—

14. Length from interventricular foramen, *see Fig.* 605 B (2·5 cm., Orley; Davidoff and Dyke) 3·2 cm.
15. Distance from tip of anterior horn to concavity of trigone, *see Fig.* 605 B (5·9 cm., Torkildsen, 1934, a, b) 6·5 cm.

Trigones :—

16. Length from anterior concavity to posterior convexity determined by extending curve of roof to meet floor (*Fig.* 605 B) 2·1 cm.

Posterior horns :—

17. Length from posterior end of trigone (*Fig.* 605 B). Varies from 3·4 cm. to nil. Average when present 2·0 cm.

Temporal horns :—

18. Length from concavity of trigone (5·0 cm., Orley; Davidoff and Dyke; 4·0 cm., Torkildsen) 4·0 cm.

Third Ventricle.—

19. Distance from interventricular foramen to chiasmatic notch, *see Fig.* 605 B (2·3–3·1 cm., Davidoff and Dyke) 1·75 cm.
20. Distance from interventricular foramen to aqueduct, *see Fig.* 605 B (2·6 cm., Orley; Davidoff and Dyke; 3·0 cm., Epstein, 1950) 2·3 cm.
21. Distance from chiasmatic notch to aqueduct (*Fig.* 605 B) 2·5 cm.
22. Size of interthalamic connexus when present (17 casts)
    Horizontal diameter 0·7 cm.
    Vertical diameter 0·5 cm.

Aqueduct.—

23. Length (1·5 cm., Orley; Davidoff and Dyke; Robertson; Sutton, 1950; 3·0 cm., Epstein) 1·75 cm.
24. Minimum diameter (0·1–0·2 cm., Orley; 0·2 cm., Robertson) 0·19 cm.

Fourth Ventricle.—

25. Length of floor (lower end of aqueduct to spinal canal, latter indicated by spine marked 'P' in *Fig.* 605 A) 2·9 cm.
26. Height of roof from floor, *see Fig.* 605 B (1·46 cm., Davidoff and Dyke; 1·5 cm., Orley; 1·6 cm., Epstein; 1·5–2·0 cm., Sutton; 1·3–2·1 cm., Robertson) 1·3 cm.

In addition to the measurements listed above the following ratios were calculated for each specimen (*Table VII*) :—

$$\frac{\text{Maximum spread of anterior horns}}{\text{Maximum breadth of brain}} = 0{\cdot}26 \; (0{\cdot}23, \text{Evans, } 1942)$$

$$\frac{\text{Maximum spread of temporal horns}}{\text{Maximum breadth of brain}} = 0{\cdot}55$$

$$\frac{\text{Tip of anterior horn to concavity of trigone (measurement 15, } \textit{Fig.} \text{ 605 B)}}{\text{Maximum length of brain}} = 0{\cdot}425$$

$$\frac{\text{Volume of ventricles}}{\text{Volume of brain}} = 0{\cdot}016$$

The measurements of the 24 adult casts recorded in *Tables II–VII* show the following general features :—

1. There is some variation in the overall dimensions and a much wider variation in the volume of the casts.

2. The overall dimensions of the casts are roughly proportional to the dimensions of the brain; the casts tend to be long and narrow in dolicocephalic brains and short and broad in brachycephalic brains, as noted by Bailey (1936).

3. The casts exhibit no correlation between their overall dimensions and their volume, because the

TABLES OF MEASUREMENTS

See pp. 527, 528 for full details of points from which measurements were made.

Table II.—General Data

Number of Specimen	Sex	Age	Length of Brain	Breadth of Brain	Volume of Brain to Nearest 5 c.c.	Capacity of Ventricles
			cm.	cm.	c.c.	c.c.
1	M.	29	18·1	13·7	1385	16·3
2	F.	37	18·6	13·3	1480	55·3
3	M.	39	18·0	13·6	1475	19·1
4	M.	54	17·1	13·8	1475	56·4
5	M.	61	17·0	13·0	1195	27·5
6	F.	38	17·3	13·4	1365	8·2
7	F.	29	15·5	13·2	1070	25·5
8	M.	34	16·8	13·1	1275	11·1
9	M.	72	18·2	14·0	1490	26·6
10	M.	62	18·2	13·9	1485	33·0
11	M.	38	16·8	12·9	1275	7·4
12	M.	42	17·6	13·3	1430	56·6
13	M.	60	17·0	12·3	1160	10·9
14	M.	64	16·5	13·4	1425	18·4
15	M.	73	16·6	12·4	1175	19·4
16	F.	64	17·1	13·9	1305	18·4
17	F.	47	16·5	12·2	1245	20·4
18	M.	53	17·4	13·9	1460	11·2
19	M.	68	19·1	14·0	1555	13·3
20	F.	64	16·4	13·4	1220	14·2
21	F.	53	18·3	13·4	1525	20·3
22	F.	62	18·1	13·6	1485	28·7
23	F.	46	17·1	12·9	1325	7·6
24	F.	41	16·5	13·2	1245	12·5
Maximum		73	19·1	14·0	1555	56·6
Minimum		29	15·5	12·2	1070	7·4
Average		51	17·3	13·3	1355	22·4
Average for males			17·4	13·4	1375	23·4
Average for females			17·1	13·2	1325	21·1
Average under 50 years			—	—	—	21·8
Average over 50 years			—	—	—	22·9

Table III.—Lateral Ventricles measured in Anteroposterior View

Number of Specimen	Bodies						Anterior Horns		Temporal Horns	
	Minimum Spread	*Angle between Roofs*	*Minimum width of Roof*		*Minimum Thickness*		*Maximum Spread*	*Minimum Width of Septum Lucidum*	*Maximum Spread*	*Spread at Tips*
			Left	Right	Left	Right				
	c.m		cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1	3·3	130°	1·7	1·7	0·7	0·6	3·4	0·1	7·4	6·0
2	3·7	130°	2·2	1·7	1·1	0·9	4·4	0·05	7·5	6·2
3	3·1	128°	1·9	1·5	0·4	0·4	3·6	0·05	7·5	6·2
4	4·1	115°	1·8	1·8	1·3	1·5	4·3	0·6*	8·3	6·8
5	3·7	128°	2·1	1·7	0·9	0·8	3·8	0·1	7·2	4·9
6	2·7	122	1·3	1·5	0·3	0·3	3·6	0·2	6·8	4·5
7	3·1	123°	1·6	1·6	0·7	0·7	3·2	0·05	7·4	6·2
8	2·5	125°	1·2	1·7	0·4	0·6	2·8	0·1	7·5	6·5
9	3·1	126°	1·6	1·6	0·8	0·7	4·1	0·2	7·2	5·6
10	3·3	135°	1·6	1·6	0·9	0·9	4·0	0·05	7·0	6·0
11	1·9	121°	0·8	1·0	0·3	0·3	4·3	0·3	6·5	5·4
12	4·0	114°	2·2	2·0	1·0	1·2	3·9	0·00	7·9	6·3
13	2·6	119°	1·6	1·1	0·5	0·5	2·9	0·05	7·5	(7·0)†
14	3·2	128°	1·5	1·4	0·6	0·6	3·4	0·1	7·5	6·3
15	2·6	123°	1·5	1·3	0·6	0·6	3·1	0·1	7·2	5·4
16	3·2	110°	1·3	1·7	0·7	0·8	(2·7)‡	0·2	7·6	6·2
17	2·8	115°	1·7	1·6	0·4	0·3	2·8	0·05	7·5	5·8
18	2·6	126°	1·4	1·4	0·6	0·6	3·3	0·2	7·3	5·2
19	2·5	139°	1·0	1·0	0·5	0·5	3·0	0·2	7·4	5·4
20	2·5	124°	1·2	1·5	0·5	0·5	3·3	0·1	6·5	5·1
21	2·9	126°	1·5	1·6	0·5	0·5	3·4	0·2	6·9	5·9
22	3·3	138°	1·9	1·6	1·0	0·7	3·5	0·1	6·9	5·5
23	2·8	133°	1·4	1·2	0·2	0·2	3·1	0·2	7·1	5·3
24	2·6	123°	1·3	1·3	0·6	0·5	2·9	0·05	6·9	5·0
Maximum	4·1	139°	2·2	2·0	1·3	1·5	4·4	0·6	8·3	6·8
Minimum	1·9	110°	0·8	1·0	0·2	0·2	2·8	0·00	6·5	4·5
Average	3·0	126°	1·6	1·5	0·64	0·63	3·3	0·14	7·3	5·7
Average M.	3·0	126°	1·6	1·5	0·68	0·70	3·5	0·15	7·4	5·8
Average F.	3·0	126°	1·6	1·5	0·60	0·54	3·0	0·12	7·1	5·6

* The cavity of the septum lucidum of this specimen was filled with resin.
† The temporal horns of this cast were incomplete. Therefore this figure is omitted from the averages.
‡ The anterior horns of this specimen were very irregular. Therefore this figure is omitted from the averages.

Table IV.—LATERAL VENTRICLES MEASURED IN LATERAL VIEW

NUMBER OF SPECIMEN	LENGTH OF BODIES		LENGTH OF ANTERIOR HORNS		LENGTH OF TRIGONES		LENGTH OF POSTERIOR HORNS		LENGTH OF TEMPORAL HORNS	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1	4·5	4·0	3·3	3·3	1·6	2·3	absent	absent	3·7	3·7
2	4·1	4·1	4·2	4·2	2·6	2·5	2·5	absent	4·8	4·6
3	4·1	4·1	3·4	3·2	2·8	1·8	1·0	0·4	4·1	4·1
4	3·5	3·5	3·6	3·6	2·6	2·4	absent	absent	4·3	4·3
5	4·1	4·1	3·4	3·2	2·2	2·2	2·1	0·4*	4·0	4·0
6	4·1	4·1	3·0	3·0	1·6	1·6	3·4	3·2	3·9	3·5
7	3·7	3·7	3·4	3·4	1·7	1·6	0·9	0·4	3·6	4·0
8	4·3	4·0	2·7	2·9	1·7	1·7	absent	2·2	4·2	3·9
9	4·5	4·5	3·3	3·3	2·7	2·5	absent*	absent*	4·0	4·3
10	4·2	4·2	3·5	3·4	2·4	2·4	3·1	3·0	4·0	4·0
11	4·2	4·2	3·0	3·0	1·6	1·6	absent	1·4	3·7	3·7
12	3·7	4·1	3·8	3·7	3·3	2·7	2·9	2·9†	4·3	4·3
13	3·9	4·2	3·4	2·9	1·8	1·6	absent	absent	3·0	3·0
14	3·7	4·1	3·1	3·0	2·3	1·5	absent	absent	3·7	3·7
15	3·8	3·8	3·1	3·0	2·2	1·9	absent	2·4	3·8	3·8
16	3·9	4·3	(2·0)‡	(2·9)‡	2·0	2·0	absent	2·6	3·6	3·6
17	3·2	3·6	3·2	3·2	3·2	2·3	1·4	2·2	3·7	3·7
18	4·2	4·2	3·1	3·0	2·1	2·0	absent	absent	3·6	4·0
19	4·8	4·8	3·5	3·5	2·1	2·1	1·0	0·6	4·2	3·6
20	3·4	3·4	2·9	2·9	2·0	1·6	2·4	2·9	3·8	3·8
21	4·4	4·4	3·2	3·3	2·0	2·1	3·2	1·1	4·2	4·2
22	4·0	4·2	3·6	3·5	2·5	2·1	2·9	absent	4·3	4·9
23	4·9	4·5	3·2	3·2	1·2	1·2	absent*	absent*	4·6	4·3
24	3·8	3·8	2·9	2·9	2·3	2·3	absent	absent	3·5	4·0
Maximum	4·9	4·8	4·2	4·2	3·3	2·7	3·4	3·2	4·8	4·9
Minimum	3·2	3·4	2·7	2·9	1·2	1·2	0·0	0·0	3·0	3·0
Average	4·0	4·1	3·3	3·2	2·2	2·0	2·2§	1·8§	3·9	4·0
Average M.	4·1	4·1	3·3	3·2	2·2	2·0	2·0§	1·6§	3·9	3·9
Average F.	3·9	4·1	3·3	3·2	2·2	2·0	2·4§	2·0§	3·9	4·1

* A small cavity was present near the posterior end of the occipital lobe. But the connexion with the rest of the ventricle, if present at all, was too narrow to allow the injection to pass.
† Very much more slender than on the other side.
‡ The anterior horns of this specimen were very irregular. Therefore this figure is omitted from the averages.
§ Average calculated only from specimens in which posterior horn was present.

Table V.—THIRD VENTRICLE

NUMBER OF SPECIMEN	ANTEROPOSTERIOR VIEW		LATERAL VIEW				
	Height	*Maximum Width*	*From Foramen of Monro to Chiasma*	*From Foramen of Monro to Aqueduct*	*From Chiasma to Aqueduct*	*Connexus Interthalamicus*	
						Horizontal diameter	Vertical diameter
	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1	2·8	0·5	1·9	2·2	2·4	0·7	0·5
2	2·2	0·9	1·9	2·1	2·7	0·6	0·5
3	1·7	0·6	1·5	2·6	2·4	absent	absent
4	3·0	1·1	2·0	2·5	2·6	0·5	0·2
5	2·4	0·6	1·8	2·2	2·8	0·6	0·5
6	2·1	0·5	1·7	2·2	2·4	0·6	0·5
7	2·0	0·6	1·6	2·0	2·2	0·6	0·4
8	2·0	0·5	1·6	2·2	2·5	0·7	0·7
9	2·1	0·6	1·6	2·3	2·4	absent	absent
10	2·1	0·5	1·6	2·3	2·5	0·8	0·5
11	2·5	0·4	1·8	2·4	2·4	absent	absent
12	2·0	0·6	1·5	2·1	2·4	0·7	0·3
13	1·6	0·5	1·4	2·3	2·4	0·6	0·6
14	2·2	0·6	1·7	2·3	2·6	0·8	0·5
15	2·0	0·5	1·6	2·2	2·3	0·5	0·4
16	2·2	0·6	1·8	2·2	2·4	0·6	0·4
17	1·9	0·6	1·8	2·3	2·4	absent	absent
18	2·2	0·4	1·7	2·3	2·2	1·4	1·1
19	2·4	0·4	1·9	2·6	2·7	absent	absent
20	2·5	0·4	2·2	2·2	2·5	absent	absent
21	2·4	0·5	2·0	2·7	2·7	0·9	0·5
22	2·0	0·5	1·8	2·1	2·3	0·8	0·5
23	2·8	0·4	2·0	2·3	2·5	absent	absent
24	1·9	0·4	1·6	2·1	2·4	0·8	0·4
Maximum	3·0	1·1	2·2	2·7	2·8	1·4	1·1
Minimum	1·6	0·4	1·4	2·0	2·2	0·0	0·0
Average	2·2	0·55	1·75	2·3	2·5	0·72*	0·50*
Average M.	2·2	0·55	1·7	2·3	2·5	0·73*	0·53*
Average F.	2·2	0·55	1·8	2·3	2·5	0·70*	0·46*

* Average calculated only from those specimens in which the connexus was present

Table VI.—Aqueduct and Fourth Ventricle

Number of Specimen	Anteroposterior View		Lateral View			
			Aqueduct		*Fourth Ventricle*	
	Minimum Width of Aqueduct	*Maximum Width of Floor of 4th Ventricle*	Length	Minimum Thickness	Length of Floor	Maximum Height of Roof
	cm.	cm.	cm.	cm.	cm.	cm.
1	0·15	2·2	1·9	0·15	2·4	1·4
2	0·15	1·6	1·2	0·15	3·1	1·4
3	0·2	1·6	1·9	0·2	3·5	1·3
4	0·15	1·9	1·6	0·2	3·2	1·2
5	0·15	2·0	1·4	0·15	2·8	1·5
6	0·15	1·5	1·9	0·2	2·1	1·2
7	0·15	1·6	1·5	0·2	2·6	1·4
8	0·2	1·2	1·6	0·2	2·1	1·2
9	0·15	2·3	1·7	0·2	2·7	1·4
10	0·2	1·8	1·8	0·2	3·4	1·7
11	0·10	1·3	2·0	0·15	2·6	1·2
12	0·2	1·6	1·7	0·2	2·7	1·1
13	0·15	1·8	1·4	0·2	3·3	1·5
14	0·15	1·6	1·6	0·2	3·0	1·5
15	0·10	1·9	2·0	0·2	2·6	1·2
16	0·15	2·0	1·9	0·2	3·1	1·2
17	0·15	2·1	1·6	0·15	3·3	1·6
18	0·15	1·7	2·0	0·2	3·5	1·3
19	0·15	1·8	2·2	0·2	3·3	1·3
20	0·2	1·4	1·8	0·2	3·7	1·3
21	0·2	1·6	1·5	0·2	3·7	1·6
22	0·10	1·2	1·9	0·2	2·6	1·2
23	0·15	1·7	2·0	0·2	2·7	1·2
24	0·15	1·3	1·9	0·15	2·8	1·1
Maximum	0·2	2·3	2·2	0·2	3·7	1·7
Minimum	0·10	1·2	1·2	0·15	2·1	1·1
Average	0·15	1·7	1·7	0·19	2·9	1·3
Average M.	0·15	1·8	1·7	0·19	2·9	1·3
Average F.	0·15	1·6	1·7	0·19	2·9	1·3

Table VII.—Ratios of Ventricles to Brains

Number of Specimen	Spread of Anterior Horns / Breadth of Brain	Spread of Temporal Horns / Breadth of Brain	Volume of Ventricles / Volume of Brain	Anterior Horn to Concavity of Trigone / Length of Brain
1	0·25	0·54	0·012	0·41
2	0·33	0·56	0·037	0·45
3	0·27	0·55	0·013	0·41
4	0·31	0·60	0·038	0·41
5	0·29	0·55	0·023	0·44
6	0·27	0·51	0·006	0·41
7	0·24	0·56	0·024	0·46
8	0·21	0·57	0·009	0·41
9	0·29	0·51	0·018	0·43
10	0·29	0·50	0·022	0·42
11	0·33	0·50	0·006	0·43
12	0·29	0·59	0·040	0·43
13	0·24	0·61	0·009	0·42
14	0·25	0·56	0·013	0·42
15	0·25	0·58	0·017	0·41
16	—	0·55	0·014	—
17	0·23	0·61	0·016	0·46
18	0·25	0·53	0·008	0·42
19	0·21	0·53	0·009	0·43
20	0·25	0·49	0·012	0·38
21	0·25	0·52	0·013	0·42
22	0·26	0·51	0·019	0·42
23	0·24	0·55	0·006	0·46
24	0·22	0·52	0·010	0·41
Maximum	0·33	0·61	0·040	0·46
Minimum	0·21	0·49	0·006	0·38
Average	0·26	0·55	0·016	0·425
Average M.	0·265	0·55	0·017	0·42
Average F.	0·255	0·55	0·015	0·43
Standard Deviation	0·0339	0·0343	0·0099	0·019
Standard error	0·0069	0·0069	0·00203	0·0041

casts of some lateral ventricles are quite slender while others of comparable length are very thick (cf., for example, *Figs.* 609, 610).

4. The volume of the casts is not proportional to the volume of the brain. Although ventricles of capacity well above the average occur only in brains well above average volume, the converse is not true. Brains of volume well above the average may contain ventricles with capacity well below the average.

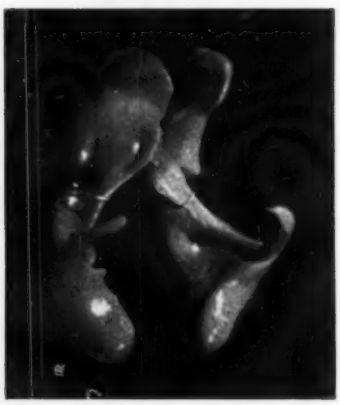

FIG. 606.—Cast of 12-weeks' fœtus; oblique ventral view to show the deep excavation of the calcar avis (natural size). The third and fourth ventricles are not injected.

5. The volume of the casts *in our small series* does not increase with age (*Table VIII*).

6. The average volume of the casts is slightly less in the female than in the male, even allowing for the smaller size of the female brain. The reduced volume of the female casts is due almost entirely to reduced thickness of the bodies of the lateral ventricles.

7. Some degree of asymmetry is present in the anterior horns and bodies of the lateral ventricles, but the measurements show no consistent difference between the two sides.

8. Asymmetry of the trigones occurs in one-third of the casts (*Table IV*).

9. The posterior horns show very great variations. At the end of the fourth month of fœtal life they are quite short but very stout, appearing as posterior prolongations of the trigone; at this stage they are symmetrical (*Fig.* 606). In the adult the persistence of well-developed posterior horns *on both sides* is

Table VIII.—CAPACITY OF VENTRICLES IN AGE GROUPS

Decade	*No. of Specimens*	*Average Capacity (c.c.)*
20–30	2	20·9
30–40	5	20·2
40–50	4	24·3
50–60	4	24·7
60–70	7	21·9
70–80	2	23·0

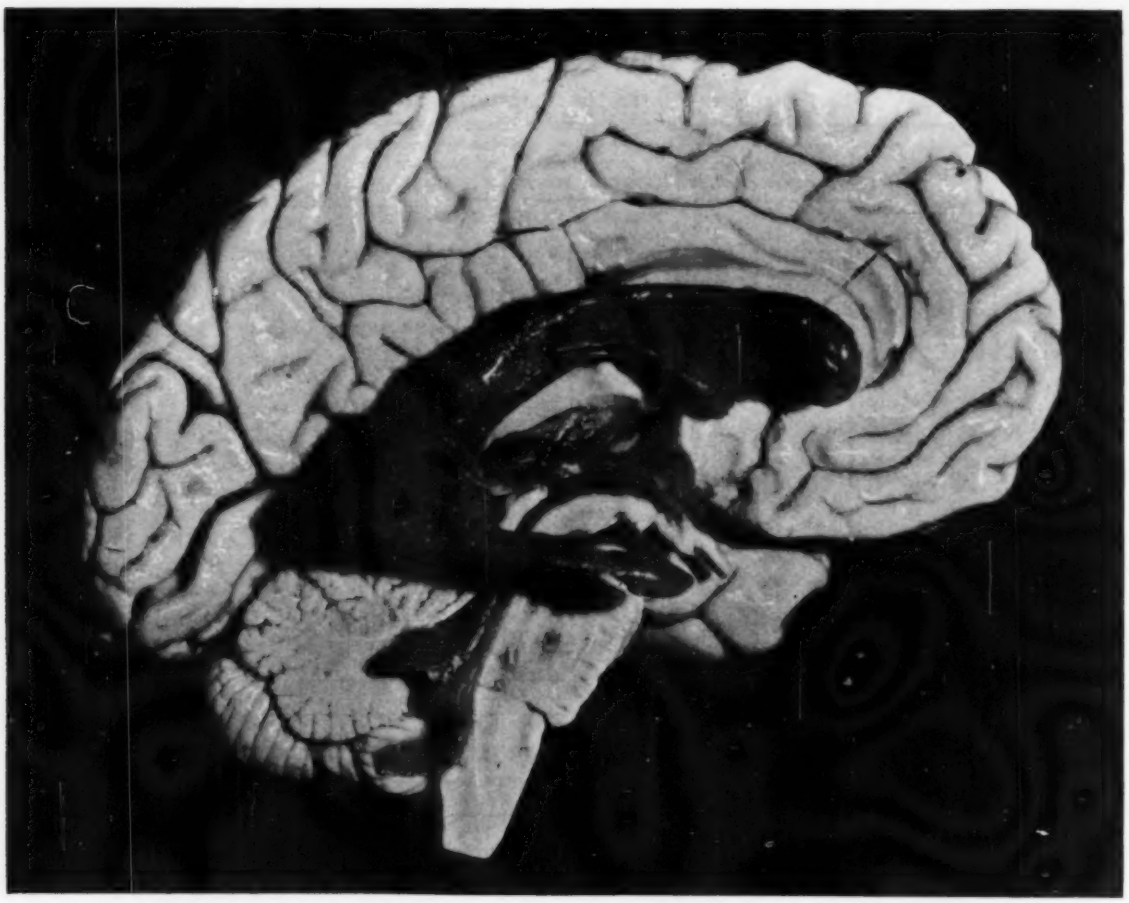

FIG. 607.—Photograph of a cast of the ventricles from which only half the brain has been removed. (× ⅔.)

exceptional. In 7 casts (29 per cent) both horns are absent. Of the remaining 17 casts, 14 (82 per cent) show very marked asymmetry in the lengths of their posterior horns, a matter which will be discussed later.

10. The third ventricle shows little variation except for the interthalamic connexus (middle commissure) which is absent in 29 per cent. When present it is of variable size and shape.

11. The measurements of these 24 adult casts do not correspond with those given by Orley (1949) and are, in the main, from 20 to 25 per cent less than in his lists of normal dimensions, which constitutes an appreciable difference in the matter of diagnosing early hydrocephalus. Orley omits to state, unfortunately, whether his measurements are of the actual ventricles or of their enlarged shadows projected on the X-ray film. The measurements given by Davidoff and Dyke (1951) are usually larger than ours.

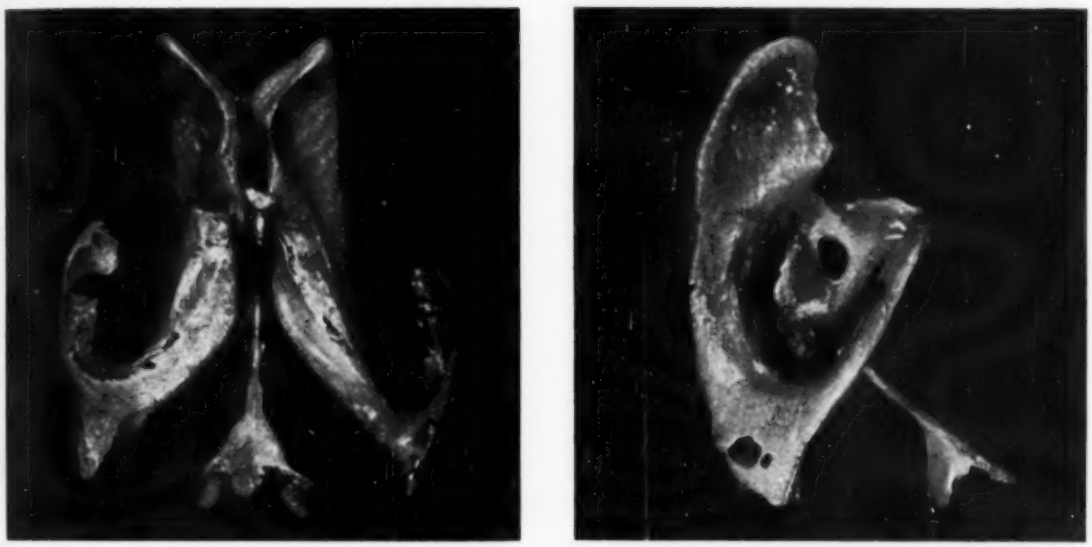

FIG. 608.—Ventral and right lateral views of cast No. 1. (× ⅔.)

ANATOMICAL FEATURES

Our technique for preparing casts of the ventricles precludes the possibility of directly assessing the relations of the ventricles to the skull, but it is possible to illustrate the relations of the ventricles to the brain by removing one half of the brain from around the cast. Such a preparation is illustrated in *Fig.* 607, from which it is easy to visualize the main radiological features of the skull.

Study of the contours of the 24 adult casts proves unexpectedly productive, and several features can be made out better from their impressions on the casts than from inspection of the actual formations in the dissected brain (*Figs.* 608–613). This is particularly so of the caudate and amygdaloid nuclei, which are difficult to see in one field of vision in the walls of the exposed ventricles. With characteristic thoroughness Retzius (1900) gave a detailed description of every feature and impression on his Wood's metal casts, and even used a hand lens to complete his inspection. It is not proposed to give such a minutely detailed recital here, and only the main features of the resin casts are recorded.

Lateral Ventricle.—

Anterior horn: The distance between the anterior horns is variable, indicating the variable width of the septum lucidum (cf. *Figs.* 609 and 610), and in one cast a 'fifth ventricle' filled with the injection. The tips of the anterior horns diverge from each other, leaving a V-shaped gap produced by the forceps minor (*Figs.* 608–613, ventral views). The antero-inferior edge of the tip of the horn may be bluntly rounded (*Fig.* 608), sharp (*Fig.* 610) or excavated into a concavity (*Fig.* 613, lateral view), indicating the variable manner in which the head of the caudate nucleus meets the forceps minor. Two or three of the casts show notches suggestive of coarctation, as described by Davidoff, 1946 (*Fig.* 610). All casts are deeply indented inferiorly by the head of the caudate nucleus (*Figs.* 608–613).

Body and trigone: The impression of the head of the caudate nucleus on the anterior horn continues into the body of the lateral ventricle as a diminishing groove (*Fig.* 608, etc.). The concave groove of the thalamus, overlaid by an irregular slit made by the choroid plexus, lies in a continuous curve with the thalamic impression on the side wall of the third ventricle. A prominent ridge between the grooves of caudate nucleus and thalamus is produced by the thalamostriate groove (*Figs.* 608, 609, 611). This ridge is itself sometimes indented by a sinuous groove produced by the thalamostriate vein when it is full of blood-clot (*Fig.* 613, right side; *Figs.* 610, 611 lateral view). In a few casts the stria semicircularis leaves a narrow groove extending into the temporal horn (*Fig.* 609, lateral view). The upper surface of the body of the lateral ventricle is transversely grooved by the fibres of the corpus callosum (*Fig.* 615 A), as noted and illustrated by Retzius (1900). It is not uncommon to find one or more of these grooves enlarged into a notch or a deep indentation on the horizon of the roof when the cast is viewed in lateral profile (e.g., *Figs.* 608, 609).

The convexity of the posterior end of the trigone is sometimes indented by the splenium (*Fig.* 613),

and occasionally there is a double indentation (*Fig.* 609, lateral view, above the notched trigone) as recorded by Torkildsen (1934, a, b). This indentation Curran (1909) from dissections of brains. Torkildsen (1934, b) wrongly attributes this latter notch to the splenium in a ventriculogram figured in his paper.

FIG. 609.—Ventral and right lateral views of cast No. 2. (× ⅔.)

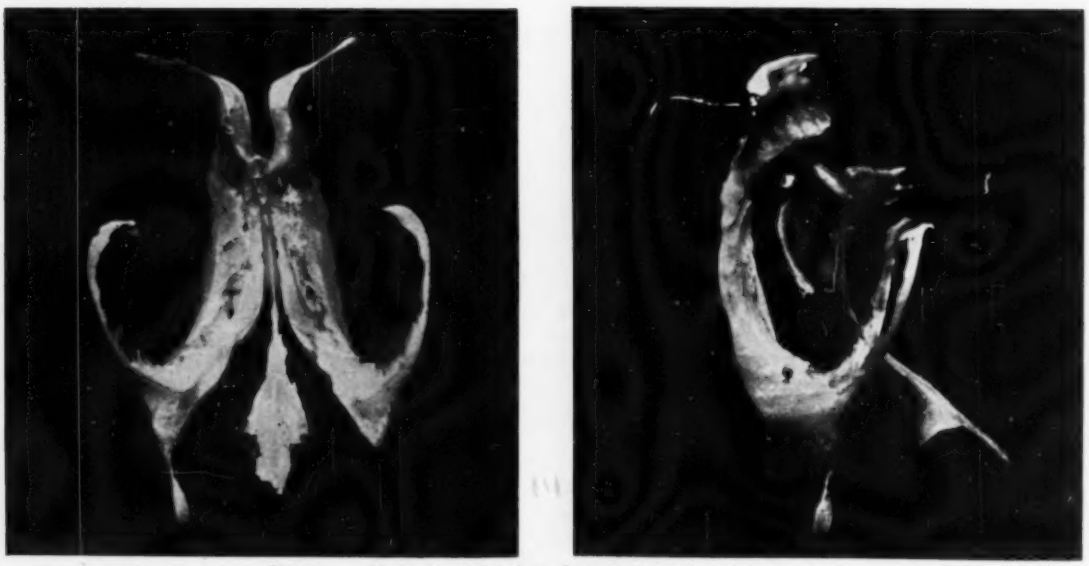

FIG. 610.—Ventral and right lateral views of cast No. 11. (× ⅔.)

by the 'bulb of the posterior horn' should not be confused with a notch seen at the posterior extremity of the trigone in cases of absence or near obliteration of the posterior horn. This latter concavity lies at a lower level and is produced by the calcar avis (e.g., *Figs.* 609 and 611, lateral view) as noted by

The inferior surface of the trigone is excavated into a shallow concavity by the convexity of the collateral eminence (produced by the collateral sulcus). The concavity is prolonged forwards into the temporal horn lateral to the groove produced by the hippocampus (*Figs.* 609, 611–613) and when the

posterior horn is well developed the collateral impression continues back along its inferior surface (*Figs.* 609, 611, and 613, ventral views).

Interventricular Foramina.—The lateral ventricle is connected to the third ventricle by a short, thick stalk of resin, representing the interventricular foramen, as in the cast so painstakingly described and illustrated by Retzius (1900). The stalks of the two sides are symmetrical, diverging slightly upwards from the side walls of the third ventricle just behind the notch made by the anterior commissure. The two stalks are joined, separately from each other, to the right and left walls of the body of the third ventricle, the roof of which projects upwards as a sharp ridge between them (*Fig.* 610, lateral view, *Fig.* 615, anteroposterior photograph and radiograph).*

Temporal horn: The impression of the tail of the caudate nucleus continues along the upper margin as a diminishing groove, which expands at the tip of the horn into a concavity produced by the amygdaloid nucleus (*Fig.* 609, lateral view). The hippocampus makes a deep groove posteriorly, on the trigone, medial to the shallow concavity of the collateral sulcus (*Fig.* 612, ventral view). The deep hippocampal groove runs forward along the temporal horn, where the cast always thins out (the roof and

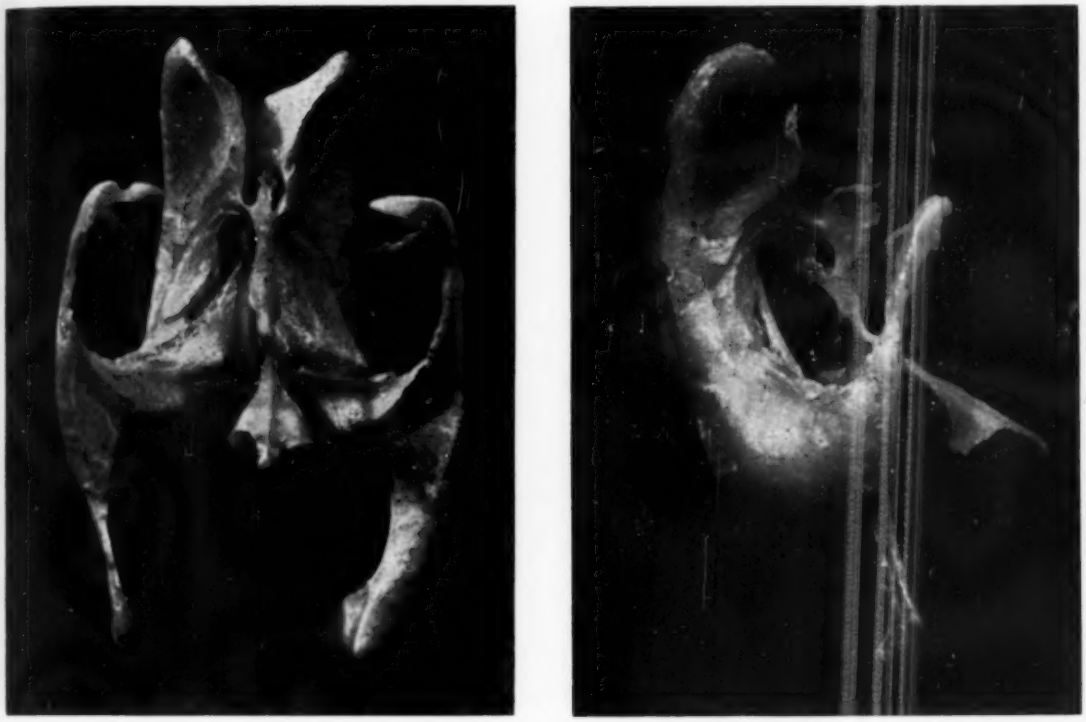

FIG. 611.—Ventral and right lateral views of cast No. 12. (× ⅔.)

* In other words, the two interventricular foramina do not join each other to make a transverse canal, and in describing them as doing so Monro (1783) was mistaken; it is possible to pass from one interventricular foramen to the other only by crossing the cavity of the third ventricle. For a century and a half the name 'foramen of Monro' has designated the passage, nowadays called 'interventricular foramen', leading from the lateral into the third ventricle, but Monro in fact described a third foramen leading from the supposed junction of the interventricular foramina into the roof of the third ventricle just behind the anterior pillars of the fornix. Fourteen years later Monro (1797) still adhered to his original description, though it should be pointed out that he was then far more concerned with proving the existence of a communication between the lateral ventricles and the third ventricle than with the actual form of the communicating foramina. It is astonishing to find Monro's false description repeated in three editions of an otherwise valuable current manual on encephalography by Davidoff and Dyke (1937, 1946, and 1951), who introduce their anatomical discourse on the ventricles by the claim that they have acquired "a fairly accurate idea of the normal appearance" of the ventricles from "the examination of the brain post mortem, the descriptions in standard anatomies (Gray, Piersol, Cunningham, Quain, Spalteholz, Key, and Retzius—*none of whom repeat Monro's error*) and the experience gained from the study of many thousands of encephalograms" (p. 73). These authors reproduce Retzius's illustration of a cast which they (incorrectly) attribute to his publication *Das Menschenchirn* (1896). Retzius's illustration was published in 1900. Davidoff and Dyke's reproduction of Retzius's illustration is labelled (incorrectly) by themselves to show the imagined midline 'foramen of Monro', though Retzius did not describe this formation in his accompanying text, and inspection of the illustration is enough to show that in Retzius's cast no such formation existed (Fig. 24, p. 74), and the illustration of the same cast from above (Fig. 25, p. 75) shows very clearly the midline ridge of the roof of the third ventricle projecting upwards between the casts of the right and left interventricular foramina, each of which can be seen opening separately into the side wall of the third ventricle. Davidoff and Dyke go further and describe in some detail the pair of interventricular foramina meeting each other and joining with

floor often touch, separated only by the choroid plexus, *Fig.* 610), but a vertical ridge of resin depends from the lateral margin of the horn (*Fig.* 612, ventral view). In other words, the hippocampal projection causes the cavity of the inferior horn to be crescentic in cross-section, as pointed out by Childe and Penfield (1937). At the inturned extremity of the horn the cast expands over the pes, which itself causes a deeply grooved indentation beneath that of the amygdaloid nucleus (*Figs.* 609, 612, ventral views).

in sagittal projections (e.g., Orley, 1949; Davidoff and Dyke, 1951), but is recognized by Torkildsen (1934, a, b) in his figures. In pneumograms the expanded tips are often overlooked or do not fill with air and the denser shadow produced by the foreshortened 'body' of the temporal horn is incorrectly interpreted as the tip of the horn (*see Figs.* 615, 617).

Posterior horn: The form of the posterior horn is, as already mentioned, much more variable than any other feature of the casts, and asymmetry of the

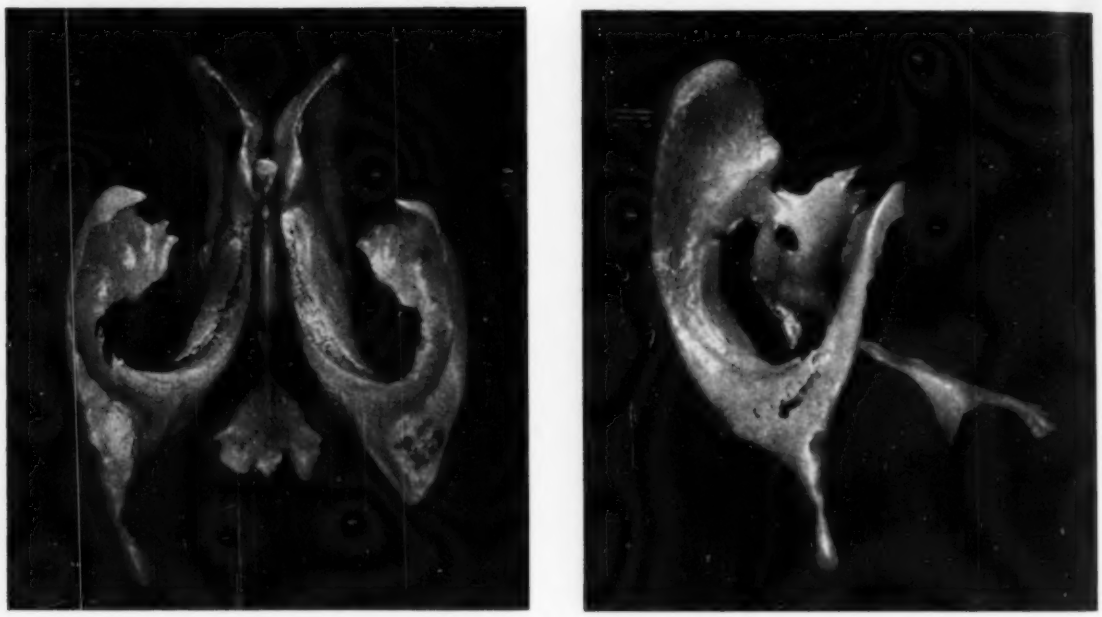

FIG. 612.—Ventral and right lateral views of cast No. 15. (× ⅔.)

The tip of the temporal horn is expanded and biconcave, due to the convexities of amygdaloid nucleus above and pes hippocampi below (*Figs.* 609, 611, 612, lateral views). These two structures often touch, in which case the cast is either fenestrated at its expanded extremity (*Fig.* 613, ventral view), or shows a crescentric or V-shaped gap (*Fig.* 611, ventral view).

The temporal horn curves forwards and downwards from the trigone, and towards its anterior end curves medially, so that the distance separating the two temporal horns is shortest between their expanded extremities (*Figs.* 608–613, ventral views). This anatomical feature is overlooked in most diagrammatic representations of ventriculographic appearance

two horns is the rule and not the exception. When the posterior horn is slender it is diminished on its medial side owing to excavation by the calcar avis (calcarine sulcus). The two posterior horns, when both are of comparable length, are more nearly symmetrical on their lateral than on their medial margins because of the asymmetrical indentations of the calcar avis on their medial sides (*Fig.* 611, ventral view). The indentation of the calcar avis is shallow or deeply concave in variable degree, with no relationship to the amount by which it excavates the medial margin of the horn. It is interesting to note that in the 5 fœtal casts of between 11 and 16 weeks the calcar avis is a boldly excavated concave groove much larger in proportion than in the adult, but that the

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the (non-existent) midline 'foramen of Monro' as a "Y-shaped tubular connection" (p. 104), the stem of which opens into the roof of the third ventricle; and they reproduce two of Monro's figures which do not show a Y-shaped channel (Fig. 55 A and B, pp. 102, 103), nor did Monro himself go so far as to describe a Y-shaped channel.

They quote as further evidence (footnote, p. 104) an irrelevant extract from Monro's work of 1783. Had they read Monro for a further three pages they might have noticed his statement that there is no connexion between the inferior part of the fourth ventricle and the central canal of the spinal cord, a further false conclusion which might have made them doubt Monro as an authority, and encouraged them to make their "examination of the brain post mortem" a little more painstaking! But they go still further, and astonishment is replaced by incredulity on finding a reproduction of an encephalogram labelled by these authors, who see a shadow in which they imagine the non-existent 'foramen of Monro' can be distinguished from the interventricular foramina (Fig. 56, p. 105)! Clearly the interpretation of encephalograms can enter the field of fanciful imagination, and if casts of the ventricles served only to correct such absurd errors the labour involved in their preparation would be well rewarded. Encephalography as a diagnostic aid has proved indispensable in modern neurology, and its precision and accuracy should not be allowed to be impaired by such imperfections in anatomical knowledge.

posterior extremity (not yet a properly developed horn) of the lateral ventricle is never obliterated by the calcar (*Fig.* 606). Subsequent development of the calcar results in an encroachment on the medial side of the posterior horn, and the final result of this encroachment may be a bulbous tip to the horn (*Figs.* 609, 612), a tear-drop-shaped cavity separated from the tip of the posterior horn, or complete obliteration of the posterior horn (*Fig.* 608). In the last case the posterior end of the trigone is concave in lateral profile from the indentation of the calcar avis (*Fig.* 609). These observations on the varying form of the posterior horn were illustrated by Dalton (1885) but received scant notice in his text, and they confirm those made by Curran (1909) from inspection of brains, by Penfield (1925) from cerebral pneumography, and by Torkildsen (1934, a, b) from measurements of his casts.

The bulb of the posterior horn (forceps major) of the splenium likewise leaves an impression varying from a broad shallow groove to a deeply concave impression. It is always present on the body above the trigone and continues into the posterior horn when the latter is present (*Fig.* 609). The impression of the collateral eminence on the inferior surface of the trigone extends backwards to encroach a little on the inferior surface of the commencement of the posterior horn (*Figs.* 609, 611–613, ventral views).

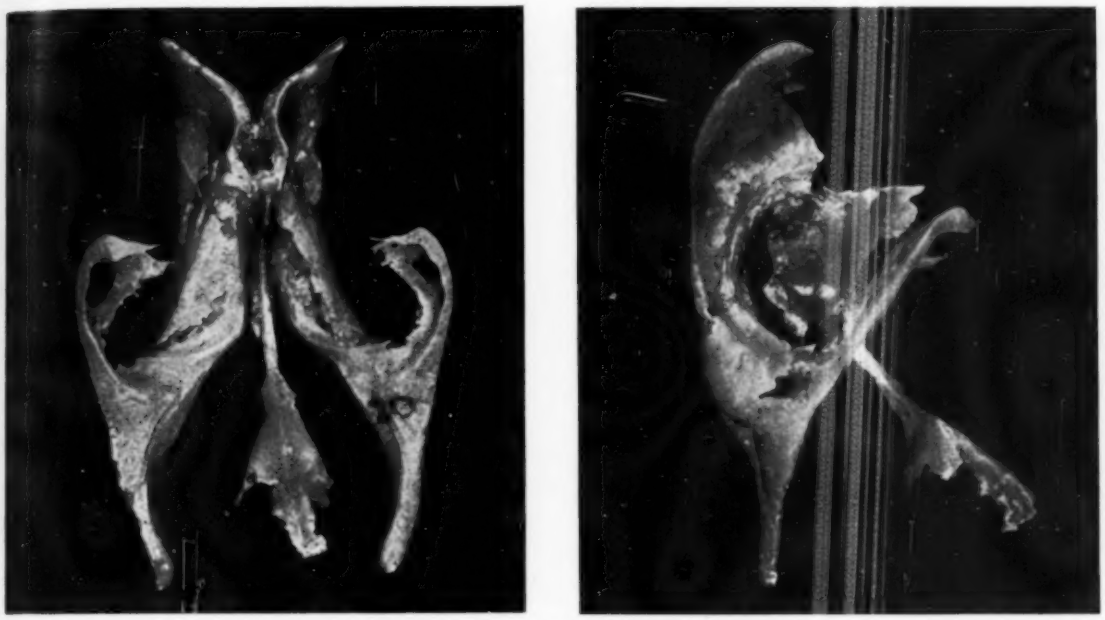


FIG. 613.—Ventral and right lateral views of cast No. 20. (× ⅔.)

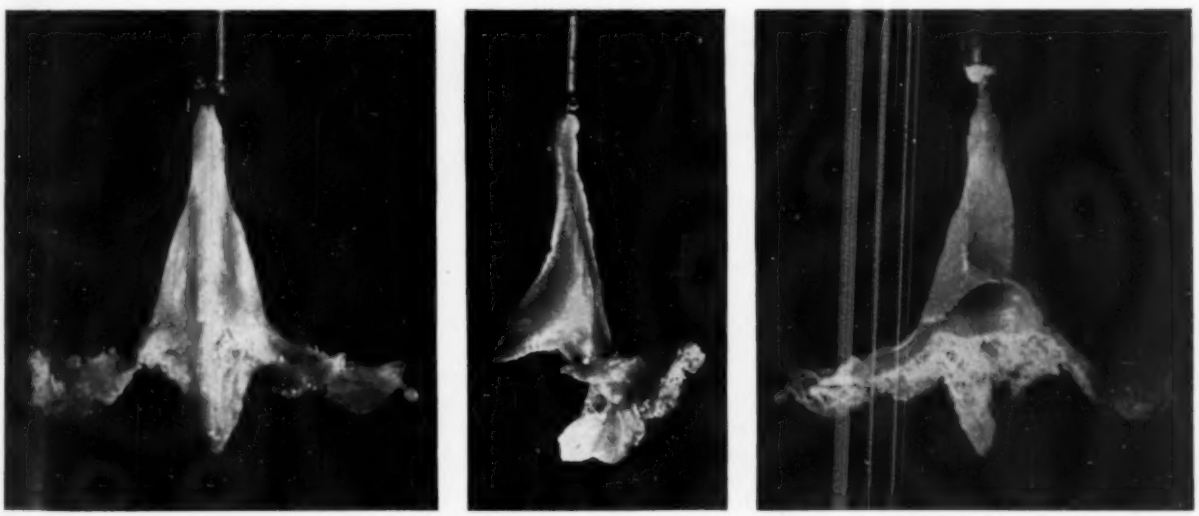


FIG. 614.—Cast of fourth ventricle made by local injection. (× 1.)

The most striking feature of our casts of the posterior horns is not, however, their variability, but their almost constant asymmetry, and we are able to find only one specific reference to this in the literature

(Robertson, 1941). In *Fig.* 608 both posterior horns are absent, in *Fig.* 613 they are roughly symmetrical, and in *Figs.* 609–612 they are asymmetrical.

Third Ventricle.—The anterior commissure leaves a notch in every cast, but the shape is rather variable from a deeply cut concavity to a wide shallow groove (*Figs.* 609, 612, lateral views). The supra-optic recess is constantly filled by the injection, and the cast shows a pointed extremity in most cases; in recess is absent in a like number. The latter is extremely variable in size (cf. *Figs.* 609–612, lateral views). The sides of the thin sheet of resin are concave, reciprocally with the convexity of the thalamus, and the two subthalamic grooves give a thickened margin to the lower border of the cast (*Figs.* 608, 612).

Aqueduct.—The outline of the cast of the aqueduct is slightly sinuous, indicating a somewhat varying

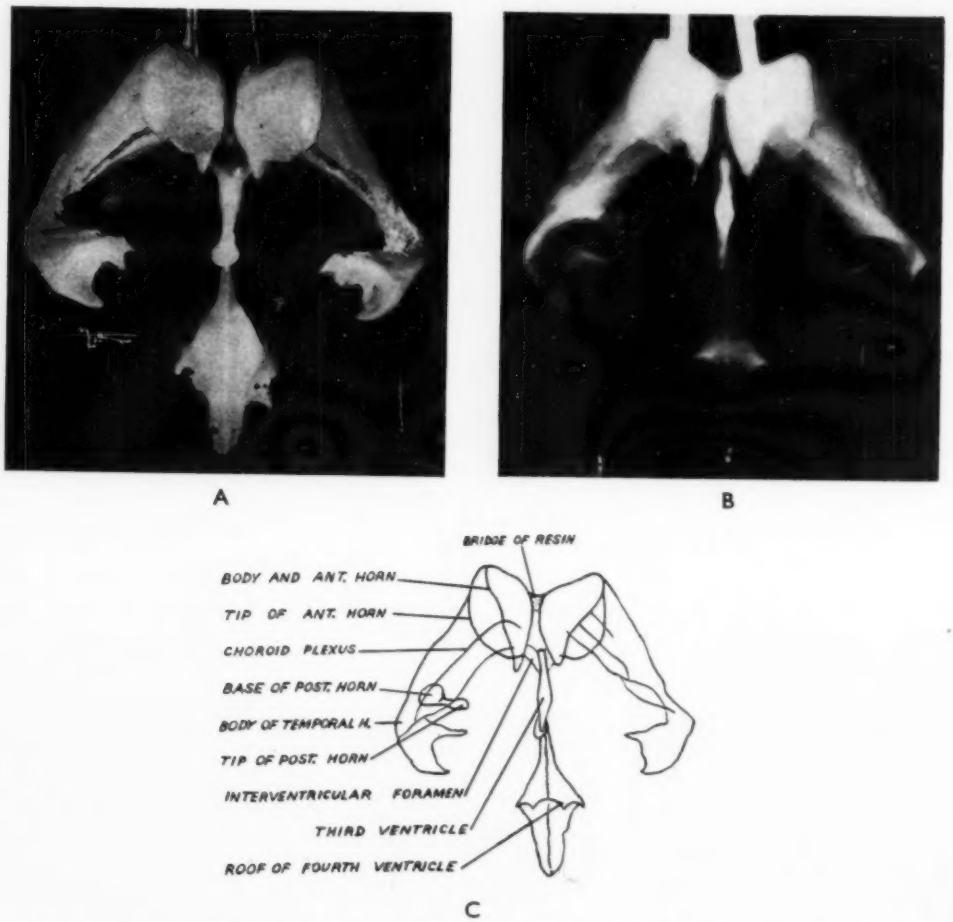


FIG. 615.—A, Anteroposterior photograph of cast No. 15 for comparison with radiograph. (× ⅔.) B, Anteroposterior projection of cast No. 15. (× ⅔.) C, Tracing of anteroposterior projection. N.B.—The bridge of resin was added to strengthen the cast.

a few it is rounded. The infundibulum of the hypophysis is also constantly filled, usually pointed but occasionally rounded. The indentation of the chiasma between these two projections is very constant in form. A spur behind the tuber cinereum indicates a shallow recess in the floor of the third ventricle mentioned by Sutton (1950) from radiological evidence, and illustrated and described by Retzius (1900), who named it the *recessus post-mammillaris* (*Figs.* 609–611, 613). It is present in 21 of the 24 casts, but it lies, in fact, *in front of* the mammillary bodies (*Fig.* 607). The interthalamic connexus (middle commissure) leaves a round window in the cast of the body of the third ventricle; it is absent (no window) in 7 of the 24 specimens (29 per cent). The posterior commissure leaves an indentation in all but three of the casts, and the suprapineal

diameter of this canal. A slight dilatation about its middle, the 'ventricle of the midbrain', is discernible in every cast. The narrowest part of the aqueduct lies anteriorly to this 'ventricle' in two-thirds, posteriorly in one-third, of the series.

Fourth Ventricle.—

Floor: The floor is characterized by a sharp midline ridge throughout its whole length (*Figs.* 608–614, ventral views). In the pontine part of the floor the eminentia facialis leaves a well-marked concavity in the cast, deeper below than above. The medullary part shows a well-marked depression corresponding to the hypoglossal triangle (*Fig.* 614), and in many casts the vagal and vestibular triangles are also seen. The lateral recesses are variably filled, the resin often having escaped before polymerization. When present they curve ventrally around the medulla.

Casts made by direct injection into the fourth ventricle show a more completely filled lateral recess (*Fig.* 614), which is in all respects similar to that figured by Retzius (1900). The cast of the lateral recess is paper thin, and crescentic in cross-section from the indentation of the choroid plexus of the fourth ventricle (*Fig.* 614, lateral view).

Roof: The cast of the roof is tent-shaped, with the deeply concave ridge lying transversely (*Fig.* 614).

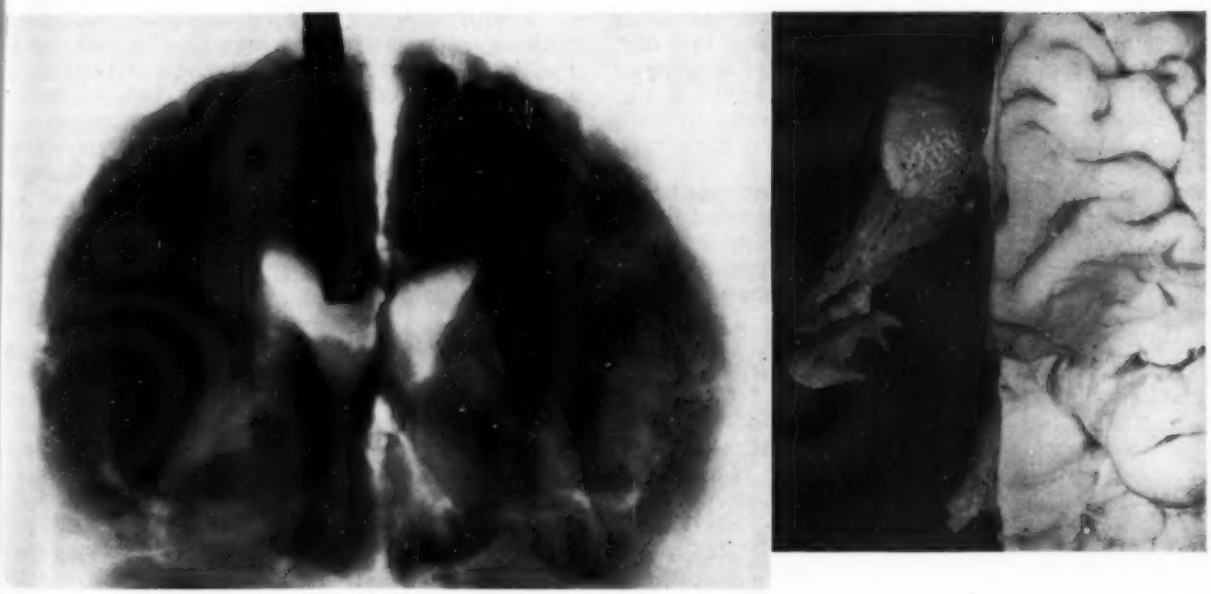
The superior wall carries a midline groove produced by the lingula, and a shallower groove on each side due to the superior cerebellar peduncle (*Fig.* 614), as noted by Twining (1939).

DISCUSSION

Technically it is difficult to prepare exact casts of the cerebral ventricles, and there is always doubt whether a given cast reproduces accurately the form

A B

FIG. 616.—A, Lateral view of cast No. 15. B, Lateral projection of cast No. 15. (× ⅔.)



A B

FIG. 617.—A, Anteroposterior pneumogram of brain with injection tube in position (note shadow of escape hole drilled in opposite hemisphere). B, Photograph for comparison of same brain after injection of resin with one-half of the brain removed from the cast. (× ⅔.) (*Fig.* 607 is lateral view of this specimen.)

The inferior wall of the tent shows a hemispherical concavity produced by the nodule of the inferior vermis of the cerebellum. The foramen of Magendie appears from our casts to be a midline slit and never a rounded hole, for in all casts a thin midline ridge of resin projects posteriorly from the lower part of the roof of the casts (*Fig.* 613—it has been clipped away in the other casts illustrated; and *Fig.* 614, lateral view).

of the living ventricles. For the reasons stated above it is believed that the resin casts made by the method detailed in *Appendix A*, while not perfect, are more accurate than those hitherto produced.

Discussion of several individual points has been made in the course of this paper, and it is desired now to mention only the two main generalizations that emerge.

Variations in Size of the Ventricles.—From the earliest workers to the most recent, stress has always been laid on the wide variations that exist, particularly in the lateral ventricles. The only exception to this is Lysholm, who wrote (1938) that "the normal ventriculogram shows an astonishing uniformity, so that in tumour cases quite definite conclusions can be drawn from quite small deformities", and again (1939), "drawings of 450 cases (of ventriculograms) subsequently proved normal indicate that the size and the shape of the normal ventricles are fairly uniform". We are at a loss to understand the basis of these statements, and we have been unable to find this opinion expressed by any other writers. Indeed, Cairns and Jupe (1951) stated that "in normal people the ventricular system shows such considerable variations in size that no precise measurements have been established", and even Davidoff and Dyke (1951) stated: "The size and shape of the lateral ventricles varies [*sic* !] somewhat within normal limits." Our results amply confirm the wide variations in ventricular size.

Asymmetry of Lateral Ventricles.—The casts described in this paper show an even more striking feature, which does not appear to have received adequate notice by previous workers, namely, asymmetry of the lateral ventricles, especially in their posterior parts. Several writers, e.g., Curran (1909), Heidrich (1927), Torkildsen (1934, a, b), Orley (1949), Davidoff and Dyke (1951), Cairns and Jupe (1951), and others, mention absence of one or both posterior horns and variations in size and shape of the posterior horns as being not infrequent, but we can find only one specific mention in the literature of asymmetry of the posterior horns when both are present.

Robertson (1941) compared the occipital horns in 90 encephalograms in which they were clearly visible. Both horns were absent in 20, one horn was absent in 20. Of the 50 cases in which both horns were present they were symmetrical in 18 and 'unequal' in 32. He recorded no measurements of the posterior horns; and he was not able to state that his 90 encephalograms were all normal.

Retzius (1900) selected for his illustration and Torkildsen (1934 a, b,) for his commercially produced brass casts what each described as a 'typical' cast. The striking feature in each is the bilateral symmetry, and it is probable that they were selected as 'typical' for that very reason. Retzius (1900) recorded no measurements, and stated that his illustration of a 'typical' cast was in fact a composite drawing made up from different parts of several broken casts. Torkildsen's wax casts showed variation in size one from another, but study of his recorded measurements shows a striking bilateral symmetry, even of the posterior horns, which is at complete variance with our own results. Of our 24 casts 7 show bilateral absence of the posterior horns. Of the remaining 17 casts, 6 show unilateral absence of a posterior horn, and of the 11 casts in which both posterior horns are present only 3 show horns of approximately equal lengths, and even in these there is a difference in thickness on the two sides. In Torkildsen's 11 casts 2 showed bilateral absence of the posterior horns, and in the remaining 9 casts, though the lengths of the horns varied between 0·3 and 3·6 cm., there was almost complete symmetry between the two sides, and in only one specimen did the lengths of the right and left horns differ by more than 0·1 cm. Torkildsen selected 13 ventriculograms for measurement. Of these, 3 showed bilateral absence of the posterior horns, 2 showed unilateral absence of a posterior horn, while of the remaining 8 no less than 6 showed symmetry of the posterior horns to within 0·5 cm. Thus Torkildsen found the posterior horns, when both are present, very variable in length but symmetrical, while we find them not only variable but very asymmetrical.

In our opinion asymmetry of the posterior horns is the rule, and a 'typical' cast, if such a thing exists, is one that shows this asymmetry (e.g., *Figs.* 609-612 but not *Fig.* 613). The midline cavities are symmetrical in their sagittal projections, but asymmetry is the usual pattern in the posterior horns. It follows that mere asymmetry of the posterior horns is, *in itself*, of no diagnostic significance in ventriculography.

Radiographs of Casts.—Many authors (Orley, 1949; Cairns and Jupe, 1951; and others) stress the value of ventricular casts as an aid in the interpretation of ventriculograms; an X-ray of the cast itself becomes an additional aid. In favour of Marco resin it may be said that without addition of radio-opaque material it gives an X-ray picture of good contrast for interpretation of shadows and for comparison with the pneumogram (*Figs.* 615, 616).

Comparison of an anteroposterior photograph with an anteroposterior radiograph of a cast such as illustrated in *Fig.* 615 facilitates the interpretation of many of the radiological features. The cast held in one's hand is of great help in interpreting its own radiograph. Torkildsen's (1934, a, b) interpretation of the sagittal projections of his six divisions is amply confirmed by our results.

The grooves produced by the choroid plexus along the anterior concavity of the trigone are easily seen in the radiograph of the casts (*Fig.* 615) and are equally prominent in the pneumogram illustrated in *Fig.* 617.

The X-ray shadows of the temporal horns are significant. They are most dense at the widest spread of the horn (*Figs.* 615, 617). This is by no means the tip; it is the anteriorly directed and therefore foreshortened 'body' of the horn. The thinned-out biconcave tips pass medially and may not cast a shadow. If they do show in a pneumogram, the shadow may be separated from the dense shadow of the widest part of the horns and may be nothing more than a thin curved line.

SUMMARY

1. A new method of making ventricular casts is described.

2. Measurements of 24 adult casts are tabulated and summarized. The casts show considerable variation in size. Asymmetry, especially posteriorly, is the rule in the lateral ventricles.

3. Anatomical features displayed in the casts are recorded. Some current errors in anatomical description are corrected.

4. The casts are a useful aid to the interpretation of pneumographic shadows.

APPENDIX A

TECHNIQUE

(*D. H. Tompsett*)

One end of a short length of brass tubing with an internal diameter of not less than 5 mm. is sharpened so that it resembles a cork borer. The blunt end of this is attached to a water vacuum pump by means of rubber tubing, and the sharp end is inserted vertically through the precentral gyrus of each cerebral hemisphere to a depth of about 5 cm. and 1·5 cm. away from the longitudinal fissure (*see Fig.* 618). After each insertion the brass tube is withdrawn and the tissue which it contains is removed by momentarily obstructing the escape of water from the vacuum pump, so that it is forced to flow out through the tube. It is easy to determine at what depth the borer enters the lateral ventricle, because the moment the latter is reached, a gurgling noise is heard as air is sucked out by the vacuum pump. The vacuum pump also prevents pieces of brain cut by the borer from falling into the ventricle and obstructing its cavity.

When holes have been made into each of the lateral ventricles, the brain is totally immersed in a basin of water, and the walls of each hole are gently scraped with a probe which has a little semicircular blade projecting at right angles from its end, in order to remove any loose fragments of brain tissue which might otherwise fall into the ventricle and possibly obstruct the interventricular foramina. Then air is blown in through one hole, to see whether it escapes quite freely from the other. If it does not, it is necessary to use the probe again to make sure that both holes are quite clear.

Occasionally it may be found to be impossible to drill holes which allow a free passage of air between the ventricles, either because the interventricular foramina are unusually small, or because one of them has become blocked by a fragment of brain tissue dislodged when the holes were bored. In these circumstances the best procedure is to inject the resin with an additional hole in each lateral ventricle. This additional hole will allow air and water displaced by the resin to escape. Even if the resin will not flow freely from one lateral ventricle to the other, the third ventricle is invariably filled, but the fourth may have to be filled later by local injection.

If it is desired to know what type of ventricles are present, i.e., whether they are slender or plump, before the cast is made, this can be discovered by taking a radiograph as illustrated in *Fig.* 617. Before taking the radiograph the ventricles must be carefully emptied of any fluid which they may contain. There is, however, another method by which a brain with plump ventricles of large cubic capacity can be identified. After the two holes have been bored into the bodies of the lateral ventricles, the brain is held upside down until all the water in the ventricles has run out. Then it is placed upside down in a basin of water. If it contains ventricles of large capacity, the brain will float until most of the air has escaped from the ventricles. However, this latter method of discovering the type of ventricles does not give such accurate information as an X-ray photograph.

It is frequently found that the lamina terminalis is slightly ruptured and the pituitary recess opened through tearing of the pituitary stalk during the removal of the brain from the cranium. In order to prevent resin from escaping from these places when the injection is made, they should first be covered with cotton-wool, and a rather thick mixture of plaster-of-Paris poured over the whole of the base of the brain. The cotton-wool prevents any of this plaster from entering the third ventricle. Although this treatment does not entirely prevent some resin from escaping from the third ventricle, it slows up

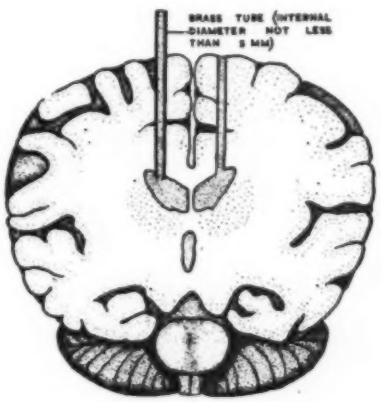


FIG. 618.—Anterior view of coronal section of brain just anterior to pons, to show brass tube inserted into one lateral ventricle and a hole bored into the other.

any leakage to such an extent that the resin sets with the third ventricle completely full of resin.

Three units of the following mixture are used for the injection of each brain :—

Marco resin 26 C	100 g.
Monomer C	15 g.
Catalyst H C H	4 g.
Brilliant yellow Marco pigment M 17	0·5 g.
Accelerator E	3 c.c.*

The above formula is suitable for working at room temperatures of about 20° C. If the temperature is in the region of 25° C., only 12 g. of monomer is used for every 100 g. of resin. If the temperature is nearer 15° C., 20 g. of monomer is used.

The catalyst is dissolved in the monomer, aided by slightly warming the latter. The yellow pigment is added to the monomer, and then the latter is mixed very thoroughly with the resin. About 30 c.c. of this mixture are decanted and placed in the refrigerator for future use. Immediately before the injection is made the accelerator is added to the rest of the mixture and mixed very thoroughly. Direct sunlight must not be allowed to fall on the resin mixture, as this may cause premature gelling.

The above mixture will become gelatinous about 15 to 20 minutes after the accelerator has been added. The exact gelling time is affected by a number of factors, the chief of which is the room temperature.

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* These materials can be obtained from Scott Bader Ltd., 109, Kingsway, London. The resin, monomer, and accelerator should be kept in a refrigerator.

Until gelling begins the resin has a treacly consistency. Gelling is rapid, being completed in about 2 minutes, but final hardening is more gradual. It is several days before maximum hardness is attained, but the resin becomes fairly hard overnight.

The injection is made in the following way: The brain is immersed in a basin of water at about 35° C. The resin mixture is poured into a glass funnel held about 1 ft. above the brain, and connected to one of the lateral ventricles by means of rubber tubing and the brass borer (*see Fig.* 619). The rubber tubing must have an internal diameter of not less than 6 mm. or the flow of resin will be too slow. Care must be

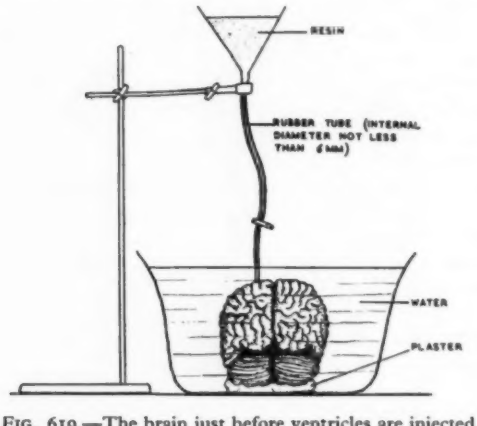

FIG. 619.—The brain just before ventricles are injected with resin.

taken when inserting the borer into the ventricle not to slice off a shaving of brain tissue from the walls of the hole. If this happens the shaving may obstruct the flow of resin.

The resin is allowed to flow into the ventricles. While this is happening the brain should be held in various positions to facilitate the escape of air and water from the ventricles via the hole in the other hemisphere. After a few minutes resin will begin to escape from this hole. This is allowed to happen until no more water or air escapes with the resin. Then resin is run in through this hole, allowing air and water, together with resin, to escape from the other. Throughout this period the temporal and occipital lobes of the cerebral hemispheres should be compressed from time to time, in order to displace water and air from the temporal and posterior horns, so that they may be filled with resin.

When no more air or water escapes from the ventricles, resin should be allowed to flow into the ventricles through one of the holes and to escape via the other until it gels. This is done to compensate for leakage of resin from the ventricles. If it appears that the resin in the funnel may be used up before the gelling time has been reached, the funnel is lowered to retard the rate of flow of the resin.

There are two reasons why the brain is submerged in water while the injection is being made. Not only does the water support most of the weight of the brain, and thus prevent distortion, but it also retards the leakage of resin which may occur at various points. The reason for using water at about 35° C. is that at this temperature any resin which may be escaping by leakage will gel slightly sooner than that in the funnel, and thus seal up the leaks, so that, as far as possible, the ventricles will be full of resin at the moment when the bulk of the resin gels.

The brain is left overnight for the resin to harden. Then most of the plaster is removed with bone forceps. Next the brain is sliced away with horizontal slices from the top, until the level of the bodies of the lateral ventricles is reached. If it is found that these are not completely filled they should be topped up with resin. When resin is required for topping up, a little of the stock of resin, which was placed in the refrigerator before the main injection was made, is transferred into a small shallow porcelain dish by means of a stirring rod. A few drops of accelerator are added and mixed in thoroughly. This mixture will gel in about 10 minutes, or less according to how many days the resin mixture has been kept in the refrigerator.

As soon as the resin used for topping up has hardened sufficiently, the work of slicing away the brain tissue is continued. In order to accelerate the hardening of the resin used for topping up, the moment this resin has gelled, the whole brain may be submerged in water at about 60° C. for about 10 minutes. It is convenient to work on two brains at a time, so that work can be continued on one while the other is set aside.

Topping up is frequently necessary in the temporal horns, the posterior horns, and the fourth ventricle. The fourth ventricle is best approached from the side of the brain, by making vertical slices through the cerebellum.

Before the cast can be freed from the remains of the base of the brain, it may be necessary to remove some resin which has escaped from the third ventricle. This can be done with bone forceps. Finally the bodies of the lateral ventricles should be joined with a bridge of transparent resin, to eliminate the risk of the interventricular foramina being broken when the casts are handled. Marco resin 28 C, to which about 10 per cent catalyst paste H and about 4 per cent accelerator E have been added, is used for making this bridge. This resin is rather less viscous than 26 C, but the viscosity increases considerably before the gelling point is reached. White plasticine is placed between the bodies of the lateral ventricles to hold the resin in position until it gels, and the resin should not be applied until it is almost on the point of gelling. This point can be recognized by the greatly increased viscosity. After the resin has hardened the plasticine can be removed.

If the aqueduct is very slender it can be reinforced by coating it with transparent resin, using the same mixture of 28 C as was used for making the bridge between the lateral ventricles. It will still be possible to see the thickness of the original yellow resin, so the specimen will not be spoiled.

The only occasion when the aqueduct is likely to be broken is when the specimen receives a sharp jolt. Fortunately it is a simple matter to repair these casts if they are broken. Fix the two ends in place with plasticine, and stick them together with either resin 26 C or 28 C.

If it is required to make a cast of the fourth ventricle which includes the lateral recesses, it is best to inject the resin directly into this ventricle. The brass tube should be inserted at right angles

into the ventral part of the pons in the midline (*see Fig. 607*). In the fixed brain the cavity of the lateral recesses is almost completely filled by the choroid plexus, so that unless at least a slight pressure can be maintained on the resin until it has become gelatinous, only an incomplete cast of these recesses can be produced. When the resin penetrates into the extremities of the lateral recesses small droplets can be seen escaping from the tiny lateral openings. If the resin flows too freely out of the large medial opening, this flow can be retarded by pressing a wad of cotton-wool firmly against it during the injection. This will cause the resin to be forced into the lateral recesses. But in a typical brain the amount of resin which remains in the lateral recesses is so slight that often it is insufficient to produce a self-supporting structure.

When casts of fœtal ventricles are prepared, some modifications of technique are necessary. The fœtal brain is far too delicate to inject after removal from the skull, so it is injected in situ, after removal of the top of the skull. But it is essential to use brains which have been perfectly hardened. It is not sufficient to place the whole fœtus in 10 per cent formalin. The brain must first be injected with formalin via the carotid artery. A very small amount of pressure will rupture the fœtal brain, so the injection of the resin should be made with a relatively fine cannula, into comparatively large holes bored into the cerebral hemispheres. The large holes allow surplus resin to escape freely. If it cannot escape freely it will soon burst the hemispheres. Double the normal amount of accelerator should be added to the resin. This gives a mixture which gels in about ten minutes.

APPENDIX B

When the injection is being made, household rubber gloves should be worn to protect the hands from the resin, which is very messy stuff.

A little detergent should be added to the water in which the brain is immersed during the injection of the resin. This facilitates the subsequent removal of the resin which escapes from the ventricles into the basin.

No attempt should be made to clean the rubber gloves after use; they should be laid on the surface of a basin of nearly boiling water for about an hour, being turned over after about half an hour. This treatment will harden the resin adhering to them, but they will still be sticky. This stickiness can be removed by dusting them with talcum powder.

Glassware should be cleaned by immersing it in boiling water containing a little detergent for at least an hour. This sets the resin hard, so that it can be removed.

Resin can be removed from the interior of the rubber tubing about half an hour after it has gelled, by directing a jet of hot water from the tap through it. The pressure of the water expands the tubing and the still flexible resin comes out in one piece. To ensure that the tubing is really clean, several pieces of tightly rolled cotton-wool are forced just inside the rubber tubing and then driven right through by a jet of hot water.

The brass borer must be cleaned immediately the resin has gelled, first by pushing a metal plunger through to remove the bulk of the resin which is still quite soft, and then by washing it in acetone, and pushing small wads of cotton-wool soaked in acetone through it. If the resin has been allowed to harden in the borer, it can only be removed by burning it out. This produces a most unpleasant form of soot which floats through the air, and settles on everything else in the room.

Unset resin can be removed from the hands and from equipment by means of a swab of cotton-wool soaked in acetone.

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THYROIDECTOMY: A REVIEW OF 1000 CONSECUTIVE CASES

By M. J. LANGE, London

PREPARATION

The Goitre Unit at the New End Hospital, Hampstead consists of a Physician assisted by a Registrar, and a Surgeon assisted by a Senior Registrar.

One morning a week is set aside for seeing new cases, and two afternoons for the follow-up of cases that have been operated on. The appointments system works satisfactorily.

On the first visit the patient is weighed, a specimen of urine tested, and the neck and chest X-rayed. A detailed history is then taken and the patient seen by the physician. He arrives at his diagnosis, makes a recommendation as to treatment, and the patient is then seen by the surgeon in an adjoining consulting-room. If the latter concurs, treatment is carried out as recommended. Should there be a difference of opinion, a joint consultation takes place and unanimity of opinion hammered out. At the patient's first attendance a special thyroid proforma is started and this follows the patient throughout treatment, both as an out- and in-patient.

In a recent series of 300 consecutive patients seen at the clinic, in 51·3 per cent operation had been recommended and had been carried out. In 3 per cent operation had been advised, but the patients were still being detoxicated by thiouracil, and in a further 5·3 per cent operation had been recommended but for some reason or other the patient had refused or requested a delay. Thus of every 100 patients seen at the clinic, operation is advised in approximately 60. Of the remainder, 19·6 per cent were being kept under observation. These had small colloid goitres which were considered not to be responsible for the patient's symptoms; or perhaps the patient had symptoms very suggestive of thyrotoxicosis, but no signs. Eighteen per cent were found to have no signs of thyrotoxicosis or goitre. In this group fell the conditions often confused with thyrotoxicosis, e.g., anxiety states and the climacteric. In a further 1·3 per cent a non-thyroid endocrine disorder was found, and in the remaining 1·3 per cent thiouracil treatment only had been recommended. In this last group was the young woman whose toxicosis had been initiated by a domestic upheaval, emotional crisis, etc., which could be resolved, and whose goitre was reasonably small and lacking in nodules.

It is the practice of this unit to recommend surgery in practically all cases of goitre, the non-toxic ones without preparation and the toxic ones after adequate preparation with thiouracil and iodine. The reasons for this are many: In toxic cases (after preparation) the improvement is almost invariably dramatic; there is a very small mortality-rate and a low morbidity rate; we believe that the majority of non-toxic goitres will in time become toxic and that there is a very real, though small, risk of malignant change.

If operation is considered necessary, age has not been a bar. During the past five years, to my knowledge, only two patients have been refused operation. One was a female of 84 with a large goitre who had been an invalid for years with chronic bronchitis and emphysema, and the second a male of 70. He was severely cachectic and it was considered that his goitre was not responsible for this. Subsequent investigation showed him to be suffering from an advanced carcinoma of the bronchus. Patients with a recent history of rapid onset of exophthalmos or with malignant exophthalmos are kept under observation for a long period. Thyroidectomy is not considered until it can be confidently predicted that operation will not aggravate the exophthalmos. Criteria employed are that the exophthalmos has not progressed for at least six months and that the globes are not tense or painful.

In this series it was noted that 5 patients had pulmonary tuberculosis; 1 active Pott's disease of the spine; 1 pernicious anæmia; 5 mitral stenosis; 2 diabetes mellitus; 5 peptic ulcers, and 4 had asthma. Ten patients were admitted in congestive failure. Three patients had been previously treated for thyrotoxicosis with deep X-ray therapy, and one with a radium collar. Two had myasthenia gravis, one of whom, a female of 25, had had thymectomy carried out three years before the thyroidectomy.

Non-toxic cases need no preparation and are given a date for admission some weeks ahead. Patients with pressure symptoms, e.g., stridor, are allowed to 'jump the queue' and are admitted either immediately or within a few days. Of the toxic cases, those that are considered minimally toxic are prepared with three weeks' Lugol's iodine, and the more toxic ones with thiouracil and iodine. The latter is always an out-patient procedure, the patients attending at weekly intervals for supervision and assessment. When they are considered sufficiently detoxicated the antithyroid drug is stopped, Lugol's iodine substituted, and the patient admitted approximately three weeks later. Patients are admitted one day, or at most two, before operation. The setting aside of a whole ward for thyroid cases only has been found to be a tremendous 'morale booster'—the convalescents reassure and encourage the newcomers. 'Scar' parades are frequent, serious, and critical.

The procedure outlined above leads to a regular and rapid turnover of patients and hence great economy in beds.

Of the 1000 cases under review, 21·9 per cent were considered to be non-toxic; of the 78·1 per cent toxic cases, 44·4 per cent were regarded as seriously toxic and the remaining 33·7 per cent as minimally toxic. In the latter category are included those cases with a rather vague history, perhaps slight loss of weight, increased irritability and nervousness, occasional palpitations, etc. Of the 781 toxic cases, it was considered wise to prepare 274 (35·1 per cent) with thiouracil; 29 cases (10·6 per cent) were found to be adversely affected by the thiouracils and this form of preparation had to be discontinued. Two cases were prepared with 1-methyl-2-mercapto-imidazole (Mercazole), one with partial

success and the other with complete relief of symptoms. One case reacted unfavourably to methyl thiouracil, but responded well to the propyl derivative. Patients varied greatly in their response, some being detoxicated within a few weeks, others having to persevere for months before improvement became apparent. Methyl thiouracil in doses of 200 mg. twice a day was invariably found to be adequate.

Of the 29 cases with toxic reactions to thiouracil, 2 developed agranulocytosis and are worthy of more detailed mention :—

Male, aged 36.—Course of thiouracil for thyrotoxicosis in 1946. Seen at this clinic on Jan. 13, 1948, with a toxic diffuse goitre. Started on methyl thiouracil 0·2 g. b.d. White-cell count on this date showed 12,000, with 60 per cent polymorphs. On Jan. 20 the count was 18,000 (polymorphs 56 per cent). On Feb. 3 (i.e., after 20 days' thiouracil therapy) was admitted to hospital with sore throat, headache, shivering, dysphagia, and vomiting. T.P.R., 103°, 130, 30. The fauces were acutely injected. Blood-count showed agranulocytosis and therapy with penicillin, blood transfusion, vitamin-B complex, and pentnucleotide was immediately instituted. Died on Feb. 7. Post-mortem showed bronchopneumonia and an unusually glandular thymus, no leucopoiesis in marrow of femur, and very little leucocytic response in tissues.

Female, aged 35.—Primary type of thyrotoxicosis. Admitted on Sept. 1, 1949, after three weeks' thiouracil, with 24 hours' history of sore throat and malaise. White-cell count revealed 2500 cells with 4 per cent polymorphonuclears. Treated with penicillin, pentnucleotides, and pyridoxin. Condition rapidly improved and discharged on Sept. 13 with normal white-cell count and taking Lugol's iodine in preparation for thyroidectomy. Remained well for two weeks and then re-admitted with malaise, shivering, dysphagia, and choking. Examination revealed bulbar type poliomyelitis, from which she succumbed the following day. It is a reasonable assumption that the virus had gained entrance via the agranulocytic angina some three weeks previously.

CLASSIFICATION

The classification of goitres has always been difficult. In this paper the classification is kept as simple as possible, being based essentially on the history and the clinical and the operative findings, histology playing a supporting, but secondary, role (excepting, of course, in carcinoma, tuberculosis, etc.).

On this broad basis the 1000 cases are categorized as follows :—

		Per cent
1. Diffuse toxic (primary thyrotoxicosis)		16·6
Typical Graves' disease	10·4	
Diffuse hyperplastic	6·2	
2. Single nodule		7·7
3. Inflammatory		0·1
4. Tuberculous		0·3
5. Lymphadenoid group		1·2
Typical lymphadenoid	0·3	
Pre-lymphadenoid	0·9	
6. Fibrosis of the thyroid		0·3
7. Carcinoma and sarcoma		1·4
8. The remainder		72·4

Diffuse Toxic Goitre.—The picture here is familiar to all. The sub-category of 'diffuse hyperplastic' is included as the picture is not quite the same as in the classical Graves' disease. Eye signs are usually absent in the former, and the gland itself is on the whole smaller and less vascular and friable than in the typical primary type.

Single Nodule.—In this series the single nodule was comparatively rare. In glands that at first appear to contain only a single nodule, closer inspection often reveals other nodules. In these cases the single nodule is never enucleated; it is always excised together with a surrounding zone of normal tissue.

Inflammatory.—There was only 1 case :—

Female, aged 19.—Two months' history of pain in neck, two weeks' history of lump in neck with sensation of constriction. Examination revealed a toxic, pyrexial patient, with an extremely tender, ill-defined adherent thyroid swelling. Treated with chemotherapy and local heat. Subsequent abscess formation, which was drained with the evacuation of much frank pus. Healed within a few weeks.

Tuberculous.—Of the 3 cases here included, tubercle bacilli were found in only 1 case, but the histological picture was characteristic in all.

1. *Female, aged* 22.—Has pulmonary tuberculosis. Nodular hyperplastic gland removed in 1948. Histologically, active tuberculous lesions present. Neck healed perfectly.

2. *Male, aged* 26.—Two months' history of swelling in neck, tenderness, and malaise. Explored on July 19, 1948, when a granulomatous abscess of the right lobe of the thyroid was found. Microscopy showed tuberculous granulation tissue with caseation. Tubercle bacilli found. Neck healed after two months and has remained well since. No other evidence of tuberculosis.

3. *Female, aged* 31.—Toxic diffuse goitre. Preparation with 4 weeks' thiouracil and 3 weeks' iodine. On April 27, 1951, removal of a hyperplastic colloid gland. Histology: "Foci of epithelial and giant-cell reaction indistinguishable from granulomatous tuberculosis. No bacilli seen." Neck healed normally. No other evidence of tuberculosis. Well since.

Pseudo-tuberculous lesions (giant-cell thyroiditis) must be borne in mind. This possibility is not ruled out in the third case, but in the second case tubercle bacilli were found and the first case has pulmonary tuberculosis.

Lymphadenoid Group.—The three lymphadenoid glands on section presented a homogeneous yellow-white appearance and histologically the parenchyma was almost entirely replaced by a diffuse infiltration of lymphocytes and lymphadenoid nodes with germ centres. The term 'pre-lymphadenoid' is used to denote those glands, which though not exhibiting the typical picture of a lymphadenoid goitre, would, it is considered, have done so in the course of time.

All three lymphadenoid cases needed thyroid medication soon after operation. One (female, aged 75) needed 5 gr. of thyroid daily; the second (female, aged 63) needed 4 gr. daily; whilst the third (male, aged 48) needed thyroxine, 0·3 mg. thrice daily for a considerable period. This dose was eventually reduced by two-thirds two years after operation.

Fibrosis of the Thyroid.—Brief details of the 3 cases are appended :—

Female, aged 46.—Main complaint was feeling of tightness in neck. Examination revealed a small stony-hard goitre. At operation, both lobes found to be

cartilaginous, ivory-white, with adherent strap muscles. Histology supported diagnosis. This patient needed thyroid, 1 gr. daily, after operation.

Female, aged 44.—Three months' aching in neck followed by pressure symptoms. Non-toxic. At operation, right lobe cartilaginous and adherent to strap muscles; left lobe to lesser extent so. On section, white and densely fibrotic. Six months after operation the patient was very well and euthyroid.

Female, aged 33.—Goitre present four years; severe pressure symptoms. Clinically, hard adherent gland. At operation a left fibrotic lobe was removed, the right being similarly, but to a lesser extent affected. Microscopy showed extensive fibrosis. Seven months after operation there were no signs or symptoms of hypothyroidism.

The terms 'Hashimoto's disease' and 'Riedl's thyroiditis' are purposely avoided. This keeps the classification simple and avoids the raising of controversial issues. In this connexion it is interesting to note that the three lymphadenoid patients needed large doses of thyroid soon after operation, whilst of the three cases in the fibrosis group, only one needed a small maintenance dose of thyroid. Furthermore, a not insignificant fact is that the average age of the lymphadenoid group is 62, whereas that of the fibrosis group is 41.

Malignant Disease.—Of the 14 cases in this series, 13 were unequivocally malignant and 1 was probably an early well-differentiated papillary carcinoma. Five were papillary carcinomata, 5 undifferentiated carcinoma, 1 a solid acinar scirrhous carcinoma, and 1 a Hürthle-cell carcinoma. Of the remaining 2 cases, one was a sarcoma and the other so undifferentiated as to produce a histological report: "Either a sarcoma or a carcinoma sarcomatoides."

Short notes of the 14 patients are as follows:—

Female, aged 17.—In 1942 thyroidectomy by Mr. Joll, and the notes are annotated that Mr. Joll remarked that this type of goitre was likely to recur. Recurrent mass removed in October, 1947. Histology revealed malignant change in one adenoma.

Dr. G. W., male, aged 57.—Aphonia eight years, attributed to typhus. Pressure symptoms, huskiness, and stridor for eight months. At operation in January, 1949, an extensive carcinoma invading the trachea was found. Tracheotomy was necessary. Death within forty-eight hours due to massive pulmonary collapse. Papillary carcinoma.

Female, aged 69.—Lump in neck seven years. Thyroidectomy, January, 1949. Malignant Hürthle-cell adenoma invading capsule. Has remained well.

Female, aged 67.—Lump in neck with six weeks' history of hoarseness, stridor, and dysphagia. March, 1949, partial removal of a large carcinoma involving trachea and œsophagus. Rapid regrowth, necessitating a tracheotomy and gastrostomy one month later. Died eight weeks after first operation. Undifferentiated carcinoma.

Female, aged 56.—Eight months' history of mass in neck and stridor. May, 1949, thyroidectomy. Three weeks later succumbed to sudden massive hæmatemesis resulting from acute gastritis and ulceration of stomach. Anaplastic carcinoma.

Female, aged 80.—Large lump in neck for eleven years. Recent increase in size with pain. November, 1949, partial removal. Died a few hours after operation. So highly pleomorphic as to resemble a sarcoma.

Female, aged 72.—Lump in neck for over thirty years (*Fig.* 620). Recent increase in size, with loss of weight and husky voice. Bilateral exophthalmos and lid lag.

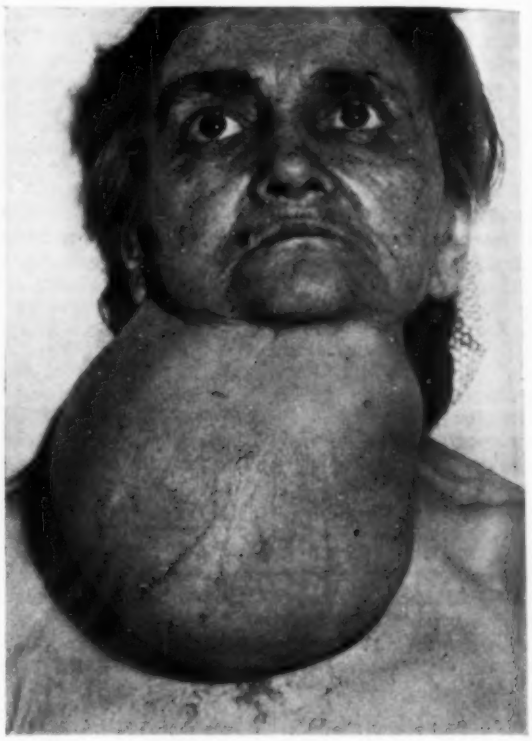

FIG. 620.—Goitre present for over thirty years. Carcinoma simplex.

January, 1950, majority of mass excised. Pressure symptoms within three weeks due to rapid regrowth, necessitating exploration and tracheotomy. Slow recovery and transferred four weeks after initial operation for deep X-ray therapy. Carcinoma simplex. (Died about ten weeks after operation.)

Female, aged 51.—Left-sided mass in thyroid. Removed September, 1950, and macroscopically was typical of non-encapsulated sclerosing tumour of Graham. Confirmed histologically. Well since operation.

Female, aged 53.—Hard mass in thyroid had been under observation at another hospital. Removed October, 1950. Pathology not definite, probably well-differentiated papillary carcinoma. Well since.

Female, aged 70.—Goitre for eight years. Recent increase in size with hoarseness. November, 1950, partial removal and tracheotomy. Death in forty-eight hours from cerebral thrombosis. Sarcoma.

Female, aged 42.—Lump in neck one year. January, 1951, removal of solid adenoma. Histology: Papillary carcinoma invading capsule and venous spaces. Referred X-ray therapy. No recurrence to date.

Female, aged 61.—Swelling in neck four years. Previous month increase in size and painful. April, 1951, hard left lobe removed—acinar scirrhous carcinoma. Deep X-ray therapy and has remained well since.

Dr. McS., male, aged 61.—Goitre noticed one month previously. May, 1951, removal of anaplastic carcinoma of left lobe, followed by X-ray therapy.

Dr. M., female, aged 68.—Lump in neck four months. Biopsy showed anaplastic giant-cell carcinoma. August, 1951, thyroidectomy followed by deep X-ray therapy.

FIG. 621.—Nodular left lobe with a normal right lobe. (× ⅔.)

Six weeks later, whilst undergoing treatment, collapsed with coronary thrombosis. Further treatment abandoned and discharged from hospital six weeks later after a stormy convalescence. (Died at home soon afterwards, probably a second coronary occlusion.)

Of these 14 malignant cases, 3 were clinically obvious carcinoma, 9 were clinically suspect, i.e., before, or at the time of, operation. The remaining

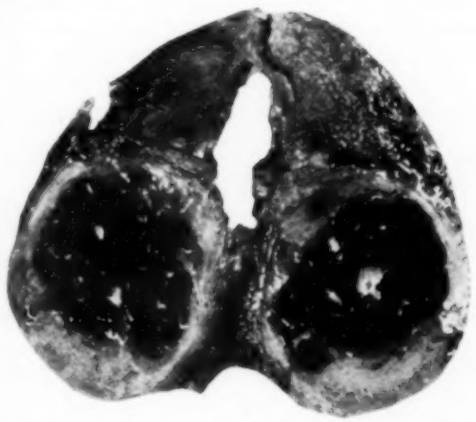

FIG. 623.—Hæmorrhage into a degenerative adenoma. (*Natural size.*)

2 were discovered after microscopy. Twelve were females, and it is interesting to note that of the 14, 3 were medical practitioners (2 male).

The Remainder.—Included in this comprehensive group are the nodular, toxic, and non-toxic; the diffuse non-toxic; the endemic colloid and the nodular goitre developing from a puberty goitre in response to stress. This latter subgroup accounted for 12·3 per cent of the total. Another group in this category that has always interested us is the unilateral type. At operation comment is frequently evoked by the fact that one lobe is replaced by nodular tissue whilst the opposite lobe is normal. Some 6 per cent of the total fall in this group (*Fig.* 621). Also included in this large category is the nodular goitre in its various stages of degeneration (*Figs.* 622, 623).

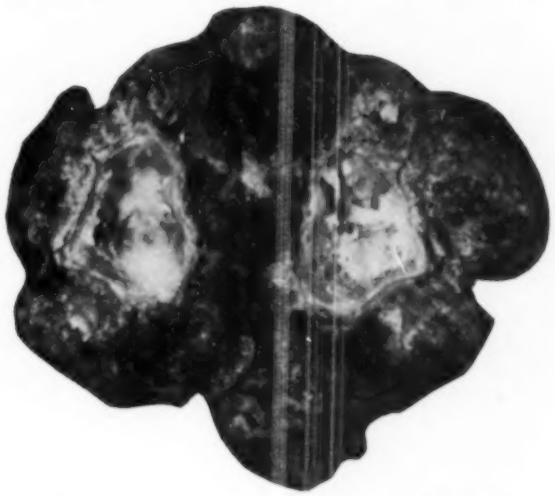

FIG. 622.—Calcified cyst in a goitre of long standing. (*Natural size.*)

REVIEW

Age and Sex.—In this series the age varied from 14 to 80 years, 2 being under 15 and 7 over 75. *Fig.* 624 shows the age distribution in 5-year periods.

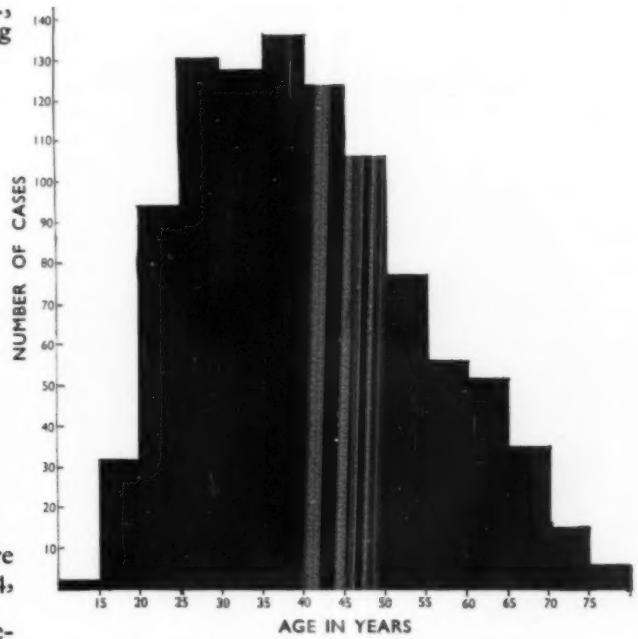

FIG. 624.—Age distribution in 5-year periods.

The distribution between the two sexes is as follows:—

	Total	*Toxic*	*Non-toxic*
Female	910	722	188
Male	90	59	31

Fig. 625 shows the age relationship to primary and secondary thyrotoxicosis.

Family History.—In determining this, only the second 500 cases are taken into account, as it was considered that the notes were not comprehensive enough in the first 500 to give an accurate index. Of the second 500, the family history is not mentioned in 68 case records, and of the remaining 432 there was a positive family history in 116 (26·9 per cent).

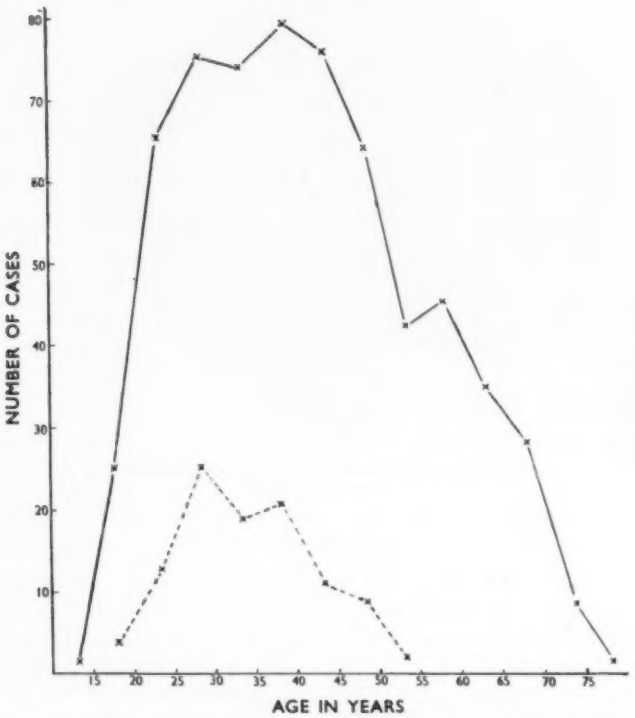

FIG. 625.—Age relationship to primary and secondary thyrotoxicosis. (Interrupted line indicates primary, and the continuous line secondary, thyrotoxicosis.)

Eye Signs.—Of the 781 toxic cases, there are no notes in reference to the eyes in 22. Of the remaining 759, eye signs were regarded as suggestive in 61 (8 per cent) and definite in 203 (26·7 per cent). Of these 203 cases, 79·3 per cent had exophthalmos. Included in these figures are 5 cases of unilateral exophthalmos and 4 of unilateral lid retraction. In the 219 cases regarded as non-toxic, 1 case was noted as having lid retraction, 3 cases lid lag, and 2 exophthalmos.

Weight Changes.—The weight changes in those rated as seriously toxic and those as minimally toxic are shown below :—

	Weight Unchanged	*Weight Increase*	*Weight Loss*	*Weight Not Recorded*
Toxic (444)	61 (13·7 per cent)	20 (4·5 per cent)	342 (77·1 per cent)	21 (4·7 per cent)
Minimally Toxic (337)	139 (41·2 per cent)	49 (14·5 per cent)	134 (39·8 per cent)	15 (4·5 per cent)

In the seriously toxic cases, the 20 cases of weight increase were all females, and of these 5 occurred in the diffuse toxic type. In the 49 minimally toxic cases with weight increase, 47 were females and all occurred in nodular goitres.

Cardiac Involvement.—Whilst cardiac involvement in thyrotoxicosis is denied by certain authorities, the following figures make this view difficult to accept.

The majority of these patients who manifest cardiac signs occur in the later decades (*Fig.* 626) and in those who have had a goitre for many years. We believe that these goitres, though often apparently non-toxic, are in fact slightly toxic (sub-clinically toxic, is perhaps the right word), and this effect exerted over a period of years eventually affects the myocardium, resulting in damage, usually manifested as auricular fibrillation, transient or established.

Of the 910 female cases, 71 manifested auricular fibrillation at some time, i.e., 7·8 per cent (or 9·8 per cent of the female patients considered to be toxic). The corresponding figures for the 12 affected males were 13·3 per cent and 20·3 per cent. It is interesting to note that in this series, though the males form only 9 per cent of the total, the incidence of cardiac involvement is twice as common in this sex.

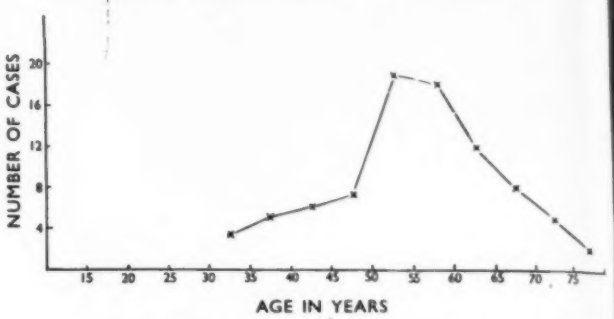

FIG. 626.—Age relationship to the thyrotoxic cardiac cases.

Of this total of 83 cases with cardiac involvement :—

- 36 exhibited paroxysmal auricular fibrillation (A.F.) pre-operatively
- 30 had established pre-operative A.F.
- 26 had transient post-operative A.F.
- 17 persistent post-operative fibrillators were restored to normal rhythm with the aid of quinidine
- 4 persisted with A.F. in spite of quinidine
- 6 reverted to normal rhythm spontaneously after operation
- 6 persisted in A.F., it being deemed inadvisable to try the effect of quinidine.

The fate of the 30 persistent pre-operative fibrillators was as follows :—

- 5 reverted to normal rhythm spontaneously
- 16 reverted to normal rhythm after a course of quinidine
- 4 persisted in fibrillation in spite of quinidine
- 5 continued in A.F. because it was considered they were not suitable subjects for quinidine therapy.

Thus 70 per cent of pre-operative established A.F. reverted to normal rhythm after operation, either spontaneously or with quinidine.

Of the 83 cases, 8 occurred in primary thyrotoxicosis, and, of these, 2 had persistent pre-operative A.F. which reverted to normal rhythm post-operatively with the aid of quinidine.

From the above figures, and the fact that this group forms over 8 per cent of a series of unselected goitres, toxic and non-toxic, the conclusion is

FIG. 627.—X-ray film showing a retrosternal goitre on the left, extending to the arch of the aorta and deviating the trachea to the right.

inescapable that thyrotoxicosis can, and does, affect the myocardium.

Pressure Symptoms.—Tracheal deviation, detectable clinically, was present in 314 (31·4 per cent) cases. (*Fig.* 627.)

FIG. 629.—Gland showing high upper poles embracing the pharynx. (*Natural size.*)

Retrosternal extensions were noted in 23·5 per cent (*Fig.* 628). On only one occasion was it necessary to split the sternum. This was in a case of carcinoma that had eroded into the trachea.

Obvious stridor was present in 3·7 per cent and suggestive in a further 1·6 per cent.

Pressure symptoms were present in a surprisingly high number—37·7 per cent. In an additional 4·7 per cent the history was very suggestive, and in

FIG. 628.—Retrosternal gland on left. ($\times \frac{7}{10}$.) The radiograph of this gland is shown in *Fig.* 627.

another 3·2 per cent pressure symptoms were complained of only after thiouracil preparation. Not well recognized are those cases with high upper poles which embrace the pharynx and give rise to a sense of constriction. (*Figs.* 629, 630.)

Anæsthesia.—All cases are operated on under general anæsthesia. The average patient is prepared by a hypodermic injection of $\frac{1}{3}$ gr. of omnopon and $\frac{1}{150}$ gr. of scopolamine one hour before operation.

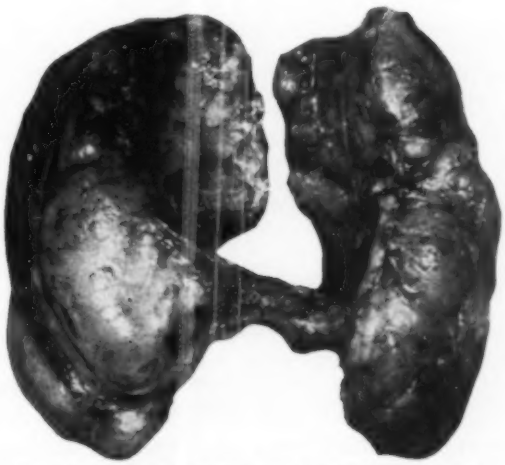

FIG. 630.—Gland showing upper poles extending well posteriorly. ($\times \frac{3}{4}$.)

Half this dose is repeated half-an-hour before the operation. In the theatre anæsthesia is induced with thiopentone and maintained with nitrous oxide and oxygen. Recently this technique has been

augmented by the intramuscular injection of pethidine (usually in 50-mg. doses) immediately before the operation commences. This undoubtedly makes for a smoother anæsthetic and prolongs the post-operative euphoria. Endotracheal anæsthesia was considered necessary in 4·9 per cent of cases, this procedure being reserved for cases with stridor or where difficulty is anticipated in the delivery of the gland, e.g., large retrosternal projections.

Operative Technique.—The operative technique adopted at this unit is fully described elsewhere (Piercy, 1950). In this series it was considered necessary to section the strap muscles in 17·6 per cent of patients, and of these 176 cases, 144 needed section on one side only.

Of 619 cases drained, 440 had unilateral drainage.

Recurrence.—In this series 46 patients had had previous operations for goitre, and of these, 5 had had two previous operations. Of these 46 recurrent cases, 7 were recurrences of this unit and are worthy of more detailed study as several important facts emerge.

1. *Female, aged* 39.—March 4, 1947, removal of a bilateral nodular goitre. Five months later there was an obvious enlargement of a pyramidal lobe which had been left behind. This was removed on Aug. 28, and there has been no recurrence since.

2. *Female, aged* 57.—March 7, 1947, partial thyroidectomy for a nodular goitre. Six months later the patient presented herself with an obvious enlargement of the pyramidal lobe. This was removed on Sept. 22. Well since.

3. *Female, aged* 39.—March 9, 1942, nodular goitre removed, neither inferior thyroid artery being ligated. Six years later recurrence on left side, which was removed on April 23, 1948, and the inferior artery ligated. Well since.

4. *Female, aged* 47.—1933, thyroidectomy at another unit. March 21, 1944, recurrence on right side removed at this unit. May 28, 1948, operation for recurrence on left side and inferior artery ligated.

5. *Female, aged* 41.—Thyroidectomy, April 28, 1945, only the left inferior thyroid artery being ligated. Four-and-a-half years later recurrence on the right side, which was removed on Oct. 12, 1949.

6. *Female, aged* 35.—Sept. 11, 1942, partial thyroidectomy, neither inferior thyroid artery being ligated. Nine years later recurrence on left, which was removed on March 2, 1951, the left inferior artery being sought and ligated.

7. *Female, aged* 42.—Dec. 12, 1949, partial thyroidectomy for a nodular goitre, it being noted at this operation that the left inferior artery was ligated, but not the right, on account of its insignificant size. Two years later recurrence on the right side. Operation, Sept. 8, 1951, and it was noted on this occasion that the artery (which was then ligated) was of considerable size!

From the above, and the operative findings of recurrences coming from other hospitals, the following three cardinal principles have crystallized :—

a. Always seek for a pyramidal lobe, and when present, remove it *in toto*, dissecting it up to, or even beyond, the hyoid. A partial thyroidectomy leaving behind the pyramidal lobe undoubtedly results in its rapid enlargement (*see* the first two cases *above*).

b. The inferior thyroid arteries are always sought and ligated, whatever their size (*Cases* 3–7 *above*).

c. Of recent years the technique of selective partial thyroidectomy has been evolved. Here all pathological tissue is removed. In many instances the remnants left behind would consist of strips of very attenuated secreting tissue which had been peeled off the nodular masses.

With the above in mind, we confidently look forward to a very much reduced recurrence rate in the next 1000 cases.

Pregnancy.—Pregnancy has not been a bar to operation, the optimum period being from the third to the sixth month of gestation. Sixteen patients were pregnant at the time of their operation and none gave rise to anxiety as regards their pregnancy.

In this connexion another case is worthy of mention. A patient, aged 36, was treated with thiouracil during the latter half of her pregnancy. After parturition it was found that the infant had a goitre which disappeared spontaneously in eight weeks.

Morbidity Rate.—Patients are now usually admitted two evenings before operation and the post-operative stay in hospital is seldom beyond the twelfth day, straightforward cases usually being discharged on the seventh, eighth, or ninth day. In this series the over-all average stay in hospital, including those admitted in cardiac failure, certain cases of prolonged post-operative stay, etc., amounts to 14·4 days. If the post-operative period only is taken as an index, this figure is reduced to 12·3 days.

Operation is invariably undertaken in the morning, and the majority of patients are drinking and having light diet the same evening. Most of the uncomplicated cases are up on the second or third day.

Complications.—

1. *Serum Collection.*—This is by far the commonest complication, occurring in 179 cases (17·9 per cent). Two categories are recognized : In the first, some blood oozes into the operation field and within a day or two of operation the neck is noted to be slightly distended. Soon afterwards discoloration of the overlying skin becomes obvious. No attempt should be made to evacuate this blood (usually clotted) at this stage. After a suitable period, when it is established by palpation that the clot has become liquefied, evacuation should be carried out. In the second category the wound appears satisfactory until about the fifth, sixth, or seventh day, when slight fluctuation is noted and evacuation reveals clear straw-coloured fluid. In this latter group it is considered that the collection of serum is due to tissue reaction resulting from the absorption of catgut in a small operation field.

We believe that the simplest way of evacuating this serum, sanguineous or otherwise, is to thrust the sterile blunt end of a needle through the scar, preferably at its lateral extremity, to seek the serum and then gently to express it. Several such expressions may be necessary, but considerable importance is attached to it, as failure to do so will inevitably lead to an adherent scar.

2. *Tetany.*—There were 17 cases of transient tetany. This usually takes the form of tingling of limbs and increased sensitivity of the facial muscles. This complication occurs within forty-eight hours of operation and is most frequently noted in the

FIG. 631.—Partly retrosternal gland showing two finger-like projections on the right. (*Approx.* × ⅔.)

diffuse hyperplastic vascular type of gland. This is probably due to the stripping of the vascular capsule and the fact that this type of gland usually occurs in the younger patient who appears more sensitive to slight variations in the serum-calcium level. These cases responded rapidly to large doses of calcium lactate (1–2 teaspoonfuls, four times a day). There were no cases of persistent tetany.

3. *Recurrent Laryngeal Nerve Paralysis.*—There were 5 cases of temporary paresis and 3 cases of permanent damage to a recurrent laryngeal nerve. All these cases were unilateral.

During the post-operative period, the ability to produce a clear-cut, explosive cough is taken as stronger evidence of intactness of the recurrent laryngeal nerve than is the voice. Tracheitis can produce a change in the voice, as, it is submitted, can excessive trauma to the accessory laryngeal

FIG. 633.—Large nodular gland, with well-marked phalanx, posteriorly, on right. (*Approx.* × ½.)

muscles. The latter two categories are of a temporary nature only. A very low-toned voice, with apparently normally functioning vocal cords, is taken as evidence of trauma to the external laryngeal nerve.

It is the practice at this unit to inspect the vocal cords of all recurrent cases. In a fair proportion, though they have a normal voice and cough, and they do not complain of the inability to shout or raise their voice, it was found that one cord was fibrotic, contracted, and immobile. Close questioning usually elicited the history that they had 'lost' their voice for several months after the first operation.

FIG. 632.—Showing a posterior projection on right and a retrosternal projection on left. (× 5/16.)

4. *Hæmorrhage.*—There were no cases which needed emergency treatment as a result of post-operative hæmorrhage. There were 3 cases, however, in which it was deemed advisable to re-open the operation site and evacuate the blood-clot. This was done where early pressure symptoms appeared to be manifesting or where it was thought that these

FIG. 634.—Side view of right lobe of *Fig.* 663. (× ½.)

might occur. No adverse effects resulted from this procedure.

5. *Adherent Scar.*—Three patients developed an adherent scar, the complaint being of a sense of discomfort. Resection of these scars, four, three, and one months after the original operation, yielded excellent results.

6. *Other Complications.*—There was no case of tracheal collapse. Ten cases became septic, but responded promptly to chemotherapy. Seven developed pulmonary complications, but yielded to routine treatment. Three developed post-operative eczema and urticaria. This was thought to be due to the use of a sulpha and peniciflin powder on the wound. Since this practice was discontinued there have been no further cases. One case developed thrombosis of the deep calf veins, but reacted well to anticoagulant therapy. One case was found to be sensitive to quinidine and collapsed after a trial dose, but fortunately recovered.

FIG. 635.—Nodular gland with posteromedial phalanx from right lobe causing severe dysphagia. (× ⅓.)

FIG. 637.—Large nodular gland showing position of ectopic masses in suprasternal area. (*Approx.* × ⅓.)

Anomalies.—Anomalies encountered in thyroid surgery, as in other regions, are numerous, and on occasion bizarre.

Already mentioned is the frequency with which only one side of the gland has undergone pathological change, the other side being normal.

The inferior thyroid veins are fairly constant, in contrast to the lateral thyroid veins, which vary in number and position. In unilateral enlargement, usually associated with tracheal deviation, the lateral thyroid veins on the affected side are frequently absent.

It is often noted with surprise at operation that, after the gland, usually a vascular one, has been removed, there remains brisk hæmorrhage from the remnant, even though the inferior thyroid artery and the superior pedicle have been ligated. One is forced to the conclusion that the tracheal and œsophageal blood-supply play a bigger role than the anatomy text-books would have one believe.

FIG. 636.—Posterior view of *Fig.* 635. (× ⅓.)

Finger-like projections from the gland are frequent and occur from almost any part. Most common are the retrosternal (or retroclavicular) (*Figs.* 631–634). Posteromedial projections are not uncommon, and usually give rise to pressure symptoms by pressing on the trachea or œsophagus (*Figs.* 635, 636). These projections are only discovered when the gland has been dislocated, and are, we believe, a potent source of recurrence owing to their frequent non-recognition.

One case had no thyroid isthmus. This occurred in a woman of 71 with a normal left lobe and a nodular right lobe. In another, a female of 41, operation revealed only a right lobe. Diligent search failed to reveal either a superior or inferior thyroid artery on the left side.

Ectopic thyroid tissue is not very uncommon. It is probably most frequent in the suprasternal notch area (*Fig.* 637) and in the carotid sheath. Histologically such masses resemble the ' parent ' gland.

The vagaries of the inferior thyroid artery are well known to every thyroid surgeon. In this series, on two occasions, the artery was noted as coming off the common carotid artery.

Mortality.—In this series there were 10 deaths. As already indicated, 5 occurred in the 14 malignant cases and the remaining 5 in 986 non-malignant goitres—0·51 per cent.

Short details of the latter five are as follows :—

1. *Female, aged* 74.—Transferred to this unit on Sept. 27, 1947, with thyrotoxicosis and auricular fibrillation. E.C.G. confirmed A.F. and myocardial damage. Practically total thyroidectomy on Oct. 3. Condition satisfactory

for the next week, but then gradually developed mental symptoms and four weeks after operation she presented a clear picture of cerebral thrombosis with monoplegia. Died on Nov. 5. Necropsy showed bronchopneumonia, cloudy swelling of the myocardium, and cerebellar softening.

2. *Female, aged* 59.—Transferred from another unit on Oct. 25, 1948, with thyrotoxicosis and congestive heart failure. Found to be hypertensive, with a severe degree of pulmonary congestion and lumbar œdema. Treated along conservative lines initially, but her condition gradually deteriorated, and it was decided to carry out stage operations. On Nov. 1, the superior thyroid vessels were ligated under local anæsthesia. Condition continued to deteriorate and she died on Nov. 3. Post-mortem showed a large retrosternal goitre displacing the œsophagus, dilated right heart, hypertrophy of left ventricle, arteriosclerotic coronaries, fatty liver, and small arteriosclerotic kidneys. (A good case could be argued for not including this patient in the series.)

3. *Male, aged* 60.—A 16-st. man with a huge goitre present for over forty years. Recently, dyspnœa, hoarseness, and increasing pressure symptoms. B.P. 190/110. Thyroidectomy on June 2, 1948, when a nodular gland weighing 868 g. was removed. Did not regain consciousness and died five hours after operation. Necropsy revealed a grossly enlarged and fatty heart.

4. *Female, aged* 70.—Oct. 26, 1948, removal of a large bosselated goitre. Up on the sixth day. Died suddenly on the twelfth day. At post-mortem a large pulmonary embolus and advanced coronary disease was found.

5. *Female, aged* 36.—Thyroidectomy at another hospital in 1945. Recurrence three years later, with accompanying signs and symptoms of thyrotoxicosis. Had been subject to asthma since the age of 3. She had a small deformed chest with poor movement and air entry. On April 27, 1949, difficult thyroidectomy. She appeared to have no reserve whatever and gradually went downhill, dying on the fifth post-operative day. Post-mortem showed bronchopneumonia and congestive cardiac failure.

It is perhaps not out of place to conclude by adding that since the last-mentioned mortality, there have been some 900 thyroidectomies (non-malignant), with but 1 death.

SUMMARY

1. One thousand unselected consecutive thyroidectomies are reviewed.

2. The low morbidity and mortality rates vindicate this unit's tenet that, with occasional exceptions, surgery remains the treatment of choice of goitre. It is freely admitted that the advent of radio-active iodine may modify this view in relation to the toxic goitre. The elderly patient with myocardial damage, little cardiac reserve, and a goitre that would be difficult to remove is now being considered for treatment with I^{131}, provided there are no severe pressure symptoms which would make surgery obligatory. Another category which merits consideration for I^{131} therapy is the recurrent case in which operative difficulties are anticipated.

3. The operability rate is over 99 per cent.

4. Principles in technique are suggested which, it is submitted, will reduce the incidence of recurrences to negligible proportions.

5. Figures are produced which indicate a high incidence of cardiac damage in goitre.

My thanks are due to Mr. J. E. Piercy and Dr. Raymond Greene for advice and helpful criticism in the preparation of this paper, and for permission to use the information in the case papers. Finally, acknowledgement to my wife for help in the collection and analysis of the figures.

REFERENCE

PIERCY, J. E. (1950), *Techniques in British Surgery* (Maingot), 40. London.

CONGENITAL DEFECTS OF THE ANTERIOR ABDOMINAL WALL *

BY GEORGE M. WYBURN

THE proper development of the embryo depends on the interaction of two forces: (*a*) the genetic mechanism inherent in the fertilized ovum; and (*b*) the influence of environmental factors such as nutrition, protection, and a suitable hormonal medium. A fault in the initial genetic endowment, if not lethal, can be responsible for the perpetuation of hereditary defects. Congenital anomalies, on the other hand, are usually due to a flaw, localized in space and time, in some aspect of the ontogenetic pattern. The causal factor here is more probably some adverse environmental influence effective on a particular developmental process and cell group. Congenital anomalies can be classified broadly as resulting from (*a*) the localized arrest of normal development—these represent the persistence of an embryonic condition and can properly be termed congenital defects; (*b*) abnormal development of a particular region, for example, teratological formations and accessory structures.

Anomalies of the anterior abdominal wall are, for the most part, congenital defects due to some interruption in the sequence of events affecting one particular phase of its development, and their classification requires a knowledge of the embryology of the ventral body wall. In pre-somite embryos with commencing head and tail folds, the ventral aspect is occupied by the wide communication of the primitive gut with the yolk-sac and, more caudally, by the mesodermal tissue of the body stalk with the allantoic diverticulum and developing blood-vessels. These together form the 'belly stalk'. At this

* Being the Arris and Gale lecture delivered at the Royal College of Surgeons of England, on June 10, 1952.

stage the tail fold includes the primitive streak and what remains of the cloacal membrane (*Fig.* 638). At a later stage the ventral aspect is formed by the

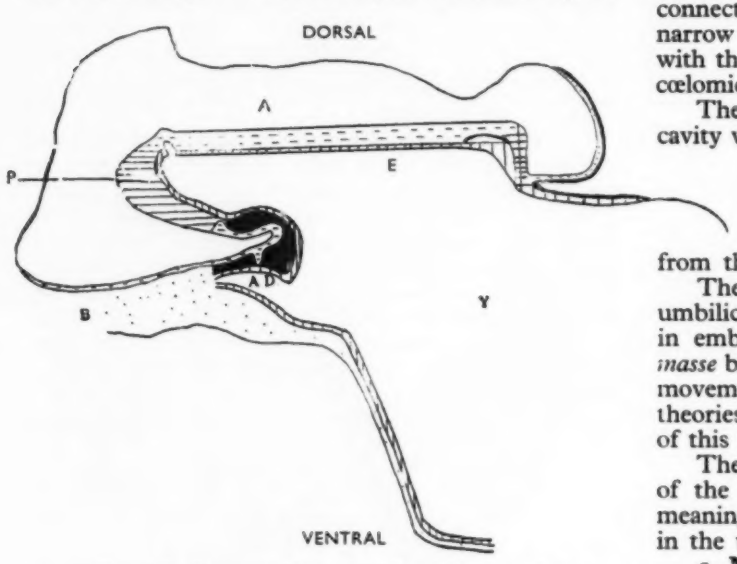

FIG. 638—Reconstruction of median sagittal section of 1·4-mm. embryo. (× 50.) A, Amniotic cavity; B, Body stalk; E, Embryonic endoderm; P, Primitive streak; Y, Yolk-sac; AD, Allantoic diverticulum.

(*Figs.* 638–644 and 647, 648 reproduced by kind permission from the '*Journal of Anatomy*'.)

ectodermal surface of the involuted pericardium, and caudal to this is the 'belly stalk' area encircled by the attachment of the amnion. This includes the still broad yolk-sac connexion and the body stalk proper with the allantois. In embryos of from 4 to 5 mm., the belly stalk is enclosed in a shallow funnel of amnion lined by thickened mesoderm. The yolk-sac connexion is now constricted to form the vitelline duct. The 'funnel' is part of and opens into the exocœlom (*Fig.* 639). A short length of umbilical cord is present in embryos of ± 7 mm. (*Fig.* 640). The tissue basis of the cord is the proliferated mesodermal lining of the enclosing amnion, and it contains the allantoic vessels, allantoic diverticulum, and part of the exocœlom left within the completed cord—the umbilical cord cœlom. This consists of a wide proximal portion which opens into the embryonic cœlom and a distal slit-like prolongation. About this time the narrowing vitelline duct becomes obliterated and finally severs its connexion with the embryonic gut. The embryonic root of the umbilical cord is sunk into the body of the embryo and as the loops of midgut develop in the ventral part of the still shallow body cavity of the embryo, they almost inevitably fall into the umbilical cord cœlom. With the growth and extension of the cord, the umbilical cord cœlom increases in size by the confluence of spaces in the cord mesenchyme until it attains its maximum size in embryos around 30 to 40 mm. By this time it contains most of the embryonic gut, which thus forms a physiological hernia (*Fig.* 641). This physiological hernia is a concomitant of the adaptive processes concerned in the evolution of the viviparous from the more primitive oviparous development of the fertilized egg.

The mesoderm at the embryonic end of the umbilical cord commences to thicken in embryos of 16 mm., and thereafter forms a ring of dense connective tissue surrounding the now relatively narrow communication of umbilical cord cœlom with the embryonic cœlom (*Fig.* 642)—the so-called cœlomic portal.

The gut is taken into the embryonic abdominal cavity when the embryo is about 42 mm. (*Fig.* 643), after which there is a gradual obliteration of the umbilical cord cœlom by proliferation of adjacent mesoderm, and in embryos of 60 mm. the body cavity is sealed off from the umbilical cord cœlom (*Fig.* 644).

There is comparatively rapid passage of the umbilical loop of intestine into the abdominal cavity in embryos of ± 40 mm. It does not do so *en masse* but slides back in regular order in a continuous movement—the cæcum last. There are many theories and suggestions regarding the mechanism of this reduction—none of them wholly satisfactory.

The terms used to denote the congenital anomalies of the abdominal wall should have embryological meaning, and the following are suggested for defects in the umbilical region.

a. **Non-formation of the Umbilical Cord** (*Fig.* 645).—In this condition, the major portion of the abdominal wall is occupied by a large thin-walled sac about the size of a hen's egg, which contains most of the abdominal viscera. A stalk or cord arises from the apex of the sac. There is no neck to the sac, which communicates widely with the body cavity of the embryo. This is one variety of exomphalos with, however, the special characteristic of

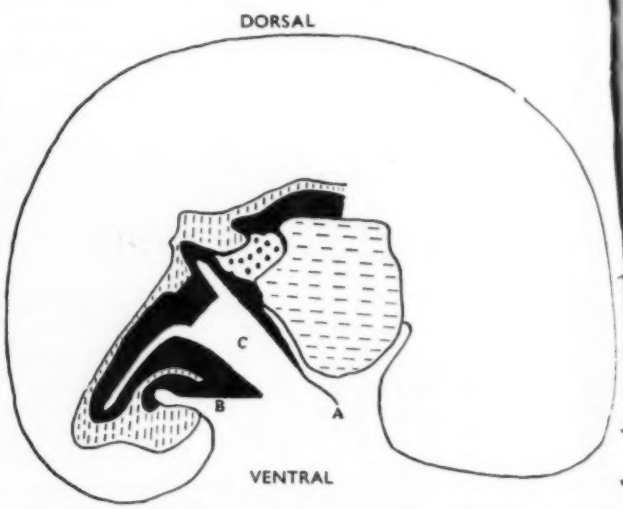

FIG. 639.—Reconstruction of a median sagittal section of 4·5-mm. embryo. (× 25.) Interrupted horizontal lines indicate pericardium; Large dots indicate liver. A, Amnion; B, Body stalk; C, Cœlom. The vitelline duct is not shown.

a supra- and infra-umbilical portion of the abdominal wall above and below the sac, and differing from cases of complete eventration in that there has been some attempt at closure of the belly stalk to form an umbilical cord. The defective development of the umbilical cord may well be related to the absence of the mesodermal condensation which is normally

present at the embryonic attachment of the cord. In consequence, there is no umbilical ring and the cœlomic portal expands *pari passu* with the exocœlom.

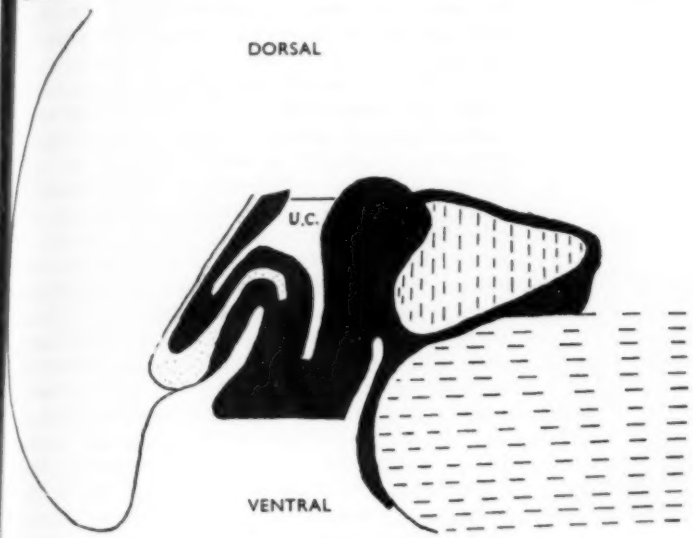

FIG. 640.—Reconstruction of median sagittal section of 7-mm. embryo. (× 25.) UC, Umbilical cord cœlom.

b. **Persistence of the Physiological Hernia** (*Fig.* 646).—Embryologically this is quite a different condition from the preceding one. There is a large sac which contains the major portion of the gut, including the cæcum and the appendix. This sac, however, communicates with the embryonic cœlom by a constricted umbilical ring. The wall of intestine is firmly adherent to the upper rim of the umbilical ring, and it is possible that this adhesion is a primary aetiological factor in some cases of persistent physiological hernia. The umbilical cord develops normally and the condition may have been brought about by a premature narrowing of the cœlomic portal due to a precocious proliferation of the fibrous tissue of the umbilical ring.

FIG. 642.—Reconstruction of median sagittal section of umbilical region of 16-mm. embryo. (× 13.) UC, Umbilical cord cœlom.

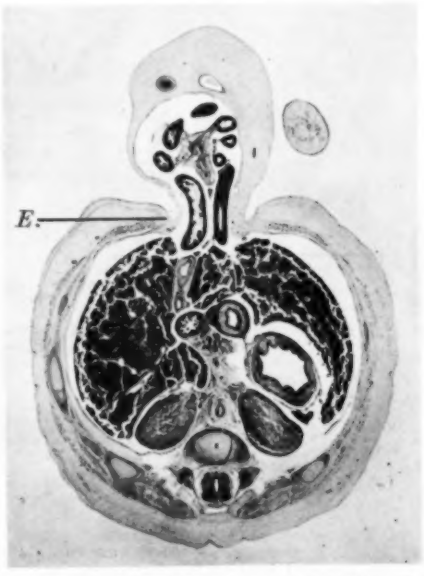

FIG. 641.—Photomicrograph of transverse section of 40-mm. embryo. (× 6.) E, Umbilical ring.

c. **Non-closure of the Umbilical Ring.**—The umbilical ring may remain patent, leaving a communication between the embryonic body cavity and a persistent umbilical cord cœlom, or a new peritoneal sac may be formed. In either case, the entrance into the sac of a loop of the bowel would result in hernia into the umbilical cord, which occurs after the reduction of the physiological hernia. This hernia may be symmetrical or asymmetrical, depending on the position of the allantoic stalk in

FIG. 643.—Photomicrograph of section of umbilical cord of 42-mm. embryo. (× 75.) E, Umbilical ring; UC, Umbilical cord cœlom.

the cord. Clinically, this is the commonest type of umbilical hernia and constitutes the simple umbilical hernia of Schwalbe and the post-natal

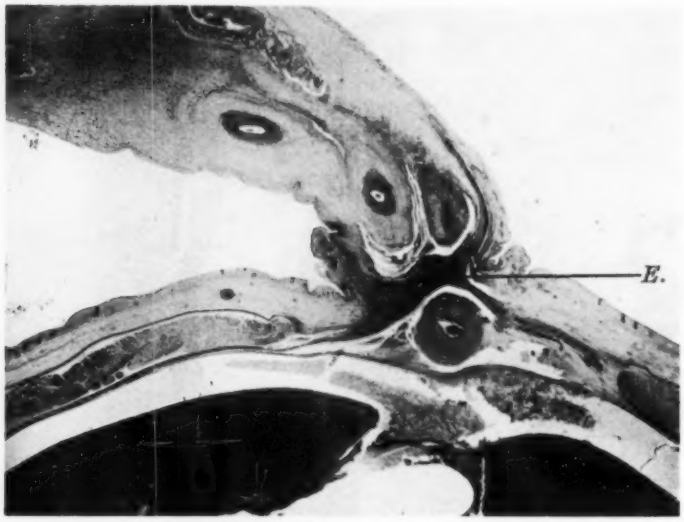

FIG. 644.—Photomicrograph of ventral body wall of 60-mm. embryo. (× 6.) E, Umbilical ring.

umbilical hernia of Fraser. It has also been called 'congenital hernia into the cord' and 'infantile hernia'.

d. **Defects of the Parietes in the Umbilical Region.**—There may be defects in the abdominal wall affecting the linea alba immediately above or below, or to one or other side of, a normal umbilicus. These are due to a defect somewhere in the umbilical ring of compact mesoderm. This leaves a potential hernial site which commonly results in a small asymmetrical hernia to one or other side of an apparently normal umbilical cord. The term 'amniotic hernia', which is in common use to describe such defects, should be discarded and replaced by 'congenital parietal hernia'.

The most significant defects of the infra-umbilical abdominal wall are associated with some degree of ectopia vesicæ or epispadias, the latter merely a minor degree of the former. In early embryos of the pre-somite stage, the cloacal membrane is relatively extensive, reaching from the cloaca up to and along the body stalk, where there is an area of contact between the amniotic ectoderm and the allantoic endoderm (*Fig.* 647). This allantoic cloacal membrane is a human characteristic. Coinciding with the appearance of the first somites, there is a piecemeal obliteration of the allantoic cloacal membrane and, in embryos of 2 to 3 mm., the membrane is limited to the cloaca proper. The obliteration is accomplished by the interpolation of mesoderm between the ectoderm and the endoderm. This mesoderm is derived from wing-like extensions from the hind end of the primitive streak which encircle the cloaca, press in towards the midline, and fuse with the mesoderm of the caudal aspect of the body stalk (*Fig.* 648). This tissue is also the mesodermal basis of the infra-umbilical portion of the abdominal wall, the genital tubercle, the external genitals, the symphysis pubis, and musculature of the bladder (*Fig.* 649). Defective development of this particular mesoderm would therefore leave the allantoic cloacal membrane occupying the area

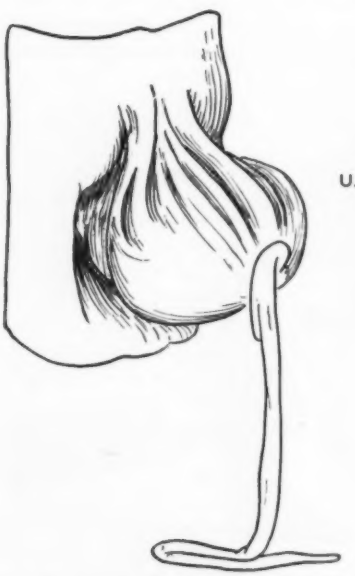

FIG. 645.—Hunterian pathological specimen showing non-formation of umbilical cord.

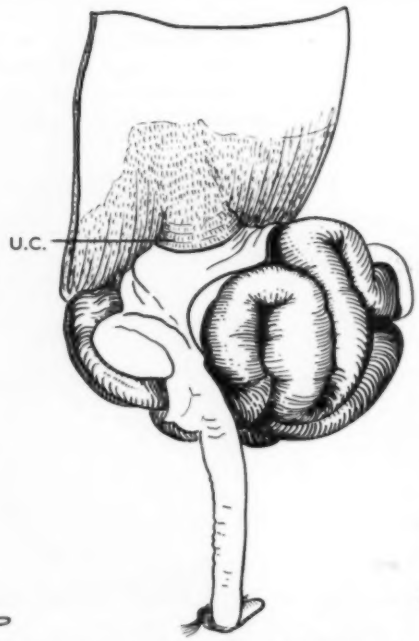

FIG. 646.—Hunterian pathological specimen showing persistence of physiological hernia and presence of umbilical ring (UC).

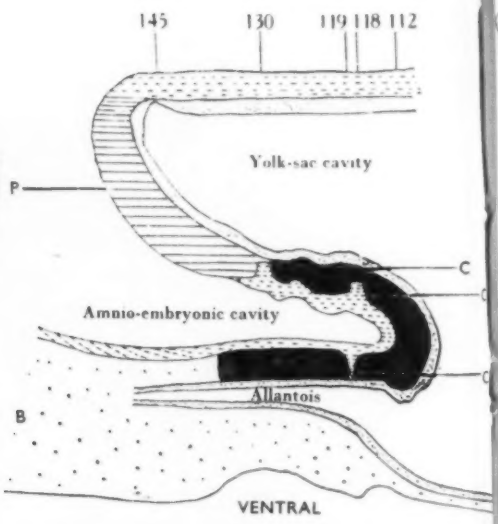

FIG. 647.—Reconstruction of median sagittal section of tail fold of 1·4-mm. embryo. (× 100.) B, Body stalk; C, Cloacal membrane; P, Primitive streak.

between the attachment of the body stalk and the cloaca (*Fig.* 650). Any persistent contact of embryonic ectoderm and endoderm inevitably breaks down and, with the absorption of this allantoic cloacal membrane which normally occurs about the second month, the condition of extroversion of the bladder would be present. The mesodermal septum, dividing the cloaca into the ventral and dorsal parts, reaches the surface at the perineum, so that the extroversion is limited to the ventral cloaca and the anal region can develop normally. There is some evidence that extroversion of the bladder is a condition peculiar to man.

These congenital abnormalities of the anterior abdominal wall are all associated with a defect of the midline mesoderm. This midline mesoderm is morphologically independent of the myotomic downgrowths from the paraxial mesoderm and is derived from the marginal mesoderm of the embryonic disk, where there is a fusion of extra-embryonic and primitive streak mesoderm. There is some evidence from comparative embryology that the extra-embryonic contribution to the marginal mesoderm attains its maximum in man in association with the precocious development of the allantois, and this shift from the established pattern of development may be correlated with the greater frequency of congenital defects of this region in man.

Explanations of congenital defects in terms of purely mechanical factors—amniotic bands, abnormal intra-uterine positions, etc.—are now discredited.

SUMMARY

1. The congenital anomalies of the anterior abdominal wall are classified according to their embryology.

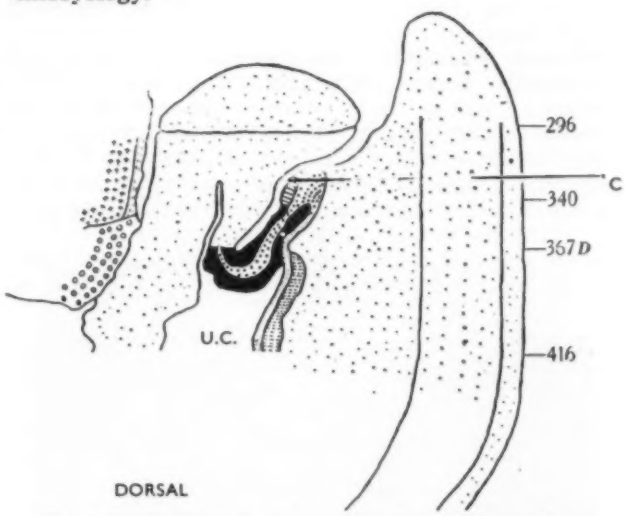

FIG. 648.—Reconstruction of caudal end of 7-mm. embryo. (× 50.) C, Cloacal membrane; UC, Umbilical cord cœlom.

2. Structurally these anomalies could result from defects of the midline mesoderm.

3. In man, the midline mesoderm has significant contributions from the extra-embryonic mesoderm in association with the precocious development of the human allantois.

FIG. 649.—Reconstruction of caudal region of normal embryo. (*After Patten and Barry, Amer. J. Anat.*, 1952, **90**, No. 1.)

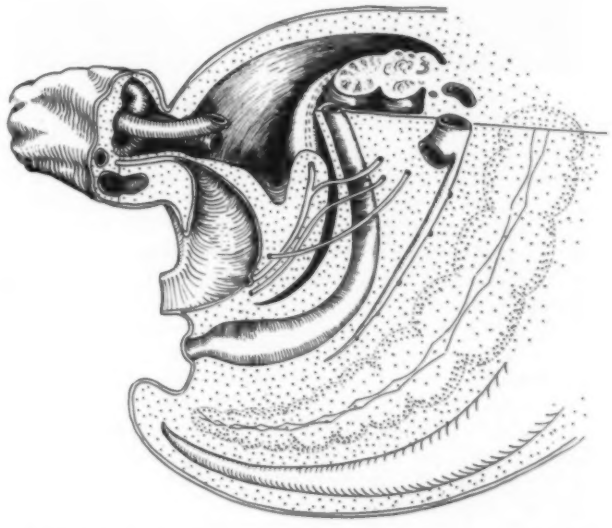

FIG. 650.—Reconstruction of caudal region of embryo showing extroversion of the bladder. (*After Patten and Barry.*)

There is considerable experimental evidence available to show that such environmental factors as nutritional deficiencies, virus infections, hormonal disturbances, may operate at specific times in the gestation period, and thereby interfere with a particular phase of a regional pattern to produce localized defects.

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CYSTS OF THE SEMILUNAR CARTILAGES OF THE KNEE-JOINT

By J. GRANT BONNIN, London

Patients with cysts of the meniscus are to be found in any Out-patient Department, but a correct diagnosis is seldom made below consultant level. A series of cases, two of them bilateral, has provided the stimulus for a fresh clinical evaluation of the disease, which in spite of its apparent simplicity, presents a number of interesting and controversial points.

The disease has been recognized as a clinical entity for barely fifty years, the first description being by Ebner in 1904. The many case reports

Fig. 651.—The classical site and appearance of a cyst of right lateral meniscus. (*Case* 2.)

which have appeared have added little to his clinical picture. Experience has widened our ideas as to the aetiology and has narrowed the operative treatment to complete removal of the meniscus. Both the clinical and the pathological aspects of the disease are of particular interest and, as a final conclusion has not yet been reached by pathologists, a brief review of their current opinions will be given before discussion of the clinical problem.

Pathology.—The cysts were first described as ganglions, which they resemble in site, content, and structure. Ganglions fall into two groups, the solitary and the multiple. Ganglions around joints in the upper extremity are more commonly unilocular and are readily cured by local excision; the excision is often only partial because it is impossible in many situations to be certain that the primary root of the ganglion has been completely eradicated from the joint or tendon-sheath. Round the knee and the ankle, the multilocular ganglion is encountered with greater frequency. (*Fig.* 651.) In the forefoot, the ganglions are again usually unilocular. Recurrence of multilocular ganglions after excision is more common and is due partly to inadequate removal of the original site from which the ganglion has developed even under the best operative conditions, and partly to the enlargement of microscopic cysts or the development of new cysts in apparently normal tissue. In addition to this there is the continued action of the primary unknown stimulus which in the knee appears to be related to the presence of the meniscus.

Multilocular ganglions show certain clinical features of importance. When the cysts are small, fluctuation is absent and they may feel rubbery or like an exostosis. When one or more cysts have enlarged, their fluid nature is more readily detected. Microscopically, the cysts consist of cavities lined by synovial tissue, often thin and tenuous, in a matrix of fibrous tissue (*Fig.* 652). Although no biochemical work appears to have been done on the contents of the cysts, this is similar to synovial fluid when the cyst is large, though it tends to be viscid in the smaller cysts.

The most interesting investigations have been concerned with the problem of the development of

Fig. 652.—Section of a cystic meniscus, showing the multilocular cavities lined by a thin synovial cell layer. Stained by hæmatoxalin and eosin. (× 10.)

the cysts. It is possible that their origin is determined by the interaction of a number of single causes, and those to which the condition has been related are as follows:—

1. *Trauma.*—The examination of case-histories will show that approximately one-third of any large group of patients give a history of trauma. There are many documented cases (4 in this series) in which the condition has commenced within a period of weeks following definite trauma, and its place in the aetiology of the condition cannot be denied.

The importance of the relationship of a torn meniscus to cyst formation is therefore great. The medial meniscus is injured six times more frequently than the lateral meniscus, yet cysts of the lateral meniscus are shown in this series to be only three times more common than cysts of the medial meniscus, and other authors give a higher figure. It suggests that some factor in the constitution of the lateral meniscus is responsible for the contrasting rates of incidence of cysts. This may be the additional synovial tissue folded around the tendon of popliteus. The discovery of a torn meniscus in relation to a cyst has always excited interest, and the cyst is often attributed to the violence causing the tear. Little attention has been paid to the possibility that the cyst may, by deforming and tying down the cartilage, contribute to the development of the tear and that the inner portion of a cystic cartilage shows degeneration which may render it more susceptible to injury. In one case reported the transverse tear present was of some standing and, in the absence of any history of injury, could be attributed to abnormal stress on the inner edge of the cartilage due to this being forcibly withdrawn from the joint by the tension of the cysts in its outer margin. Other observers (Smillie, 1946) have remarked that the tear is commonly of the 'parrot beak' type (*Fig.* 653). 'Parrot beak' tears are found in the proportion of one to twenty-three in meniscectomy for trauma, and in the cases of cysts reported here one to four; a striking contrast! Three possibilities are therefore present and have not yet been adequately distinguished :—

a. The cyst forms following trauma which has torn the cartilage.

b. The presence of the cyst renders the cartilage much more susceptible to trauma by distorting it or by producing degeneration in its more central portion.

c. An unrecognized degeneration makes the cartilage susceptible both to trauma and to cyst formation.

The puzzling group of cases, forming the majority, is that in which there is no visible trauma or degeneration present in the cartilage, and yet cysts have developed. The history of these patients bears no constant relationship to the clinical findings. Some give a history of severe injury and others of repeated trivial injury, but the majority can remember no injury at all. It would appear that trauma aggravates the disease though there is probably another factor which renders the cartilage susceptible and which in certain cases may favour the formation of cysts without any significant antecedent injury.

2. *Synovial Rests.*—A theory of the congenital inclusion of synovial tissue during the formation of the cartilage was suggested by Ollerenshaw (1921), though without any supporting evidence. The theory is obviously little more than an attempt to explain away the difficulties in relating the development of cysts to the inconstant factor of trauma. No further pathological evidence has been found to support Ollerenshaw's theory.

3. *Synovial Cell Development.*—The work of E. S. J. King (1931, 1932, and 1940) and others has shown that the earliest feature of a ganglion is the presence of a group of cells in the wall of a joint or in a tendon-sheath. These cells become spheroidal, swollen, and vacuolated; mucinoid collects between the cells; the cells thus become separated and flattened and the cyst distends. Finally the cyst is lined by a thin layer of cells resembling synovial membrane. These cells are undoubtedly synovial in origin and are not endothelial cells as stated by Ollerenshaw.

While this presents a clear picture of the development of ganglions, we are still no nearer the primary cause of the increased cellular activity, and an attempt to distinguish between a degenerative process

FIG. 653.—The typical 'parrot beak' tear together with a horizontal split in a cartilage found in association with central cystic changes extending to some extent anteriorly. (*Case* 24.)

and an active cellular reproductive process has been made (King, 1940) by an investigation of the Golgi apparatus. This special part of the protoplasm, which can be demonstrated by staining by osmic acid and impregnation with silver, is found only in cells undergoing active development. The presence of the Golgi apparatus in a hypertrophied form in cells which develop into ganglions is strongly suggestive that there is a process of cellular multiplication and active secretion, and is against the theory that ganglions are degenerative in origin. Ganglions are therefore due to the sudden proliferation of cells of a synovial type between the fibroblasts present in the ligamentous or capsular sheath to a synovial cavity, either joint or tendon-sheath. We are still uncertain whether these cells represent a metaplasia of fibroblasts or increased activity in specific synovial cells normally present but inactive, and we are also uncertain of the factor stimulating such development. This factor may be produced by trauma, though whether trauma can act on a normal cartilage or only in the presence of some preliminary degeneration, is unknown.

Clinical Features.—A classical case presents three clinical features :—

1. There is an aching pain in the knee-joint, increased by exertion and relieved by rest. This pain is often worse on first going to bed.

2. The pain is localized with accuracy and precision by the patient to a small area lying over the joint line.

3. There is a palpable and usually visible swelling on which firm pressure is painful.

With regard to the relationship of trauma, it will be found that cases fall into three approximately equal groups :—

1. Those with a definite history of severe trauma followed in a few cases by the classical features of internal derangement of the knee together with those of cystic change.

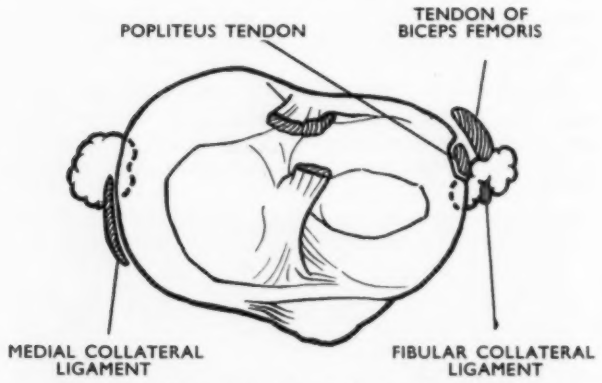


FIG. 654.—The anatomical relations of the common sites for cyst formation in the meniscii—namely, the junction of the middle and posterior third. The herniation around the posterior borders of the collateral ligaments, which makes total removal through an anterior approach difficult, is shown.

2. Those with a history of minor trauma, single or multiple, in which it is sometimes difficult to distinguish a fresh injury of the knee from strain of an abnormal knee.

FIG. 656.—Cystic changes in the lateral meniscus producing a marked erosion of the lateral edge of the tibial plateau. (*By courtesy of Sir Reginald Watson-Jones.*)

3. Those without any history of trauma. Such a history, especially when the cyst is bilateral, suggests that there is an increased susceptibility to cyst formation in certain individuals.

Pain at Night.—A number of patients who find the pain worse at night state that they cannot lie with comfort on one side, and one patient had to sleep with a pillow between the knees. No relationship was found between the side of the cyst and the side on which the patient lay for maximum comfort. It appears that the discomfort is produced by increasing the tension on the cyst and that this may be produced either by approximating the tibial plateau and the femoral condyle when lying on one side or by increasing the tension in the appropriate collateral ligament when lying on the other side.

FIG. 655.—The appearance of an anterior cyst in the lateral cartilage of the left knee.

The Cyst.—When the swelling is visible there is usually little difficulty in diagnosis. The swelling is firmly elastic, and if large is obviously fluctuant. It lies over the joint line and is related to the collateral ligament of the joint. In most cases it appears round the posterior border of the collateral ligament and is rendered tight by extension of the knee, but disappears on flexion of the knee-joint (*Fig.* 654).

Anterior Cysts.—In 25 per cent of cases the cyst presents anteriorly and in one case reported here the swelling appeared as high as the upper border of the patella. In an anterior cyst the changes in tension on flexion and extension are dependent on its size, its fixity, and the degree of herniation through the capsule of the joint. (*Fig.* 655.) A small cyst may be tense on extension and disappear on flexion when it falls back into a fatty pad, but a large cyst may be more tense on full flexion of the knee-joint. If the cyst overhangs the tibial plateau it may move more readily up and down than antero-posteriorly.

The prominence of a cyst is to some extent determined by the resistance of the capsule. This is shown by its clinical appearance in the lax area behind or in front of the collateral ligament of the joint. It is also to be noted that after inadequate

local excision, the reappearance of the swelling is often more rapid owing to the ease with which it herniates through the operation scar.

In one case involving the internal cartilage, an interesting feature was snapping of the tendon of sartorius over the cyst on flexion and extension of the knee, just as may occur over a solitary exostosis of the inner aspect of the tibia. Erosion of the tibial or femoral condyle has been reported in association with long-standing cysts, and it is well known that ganglions elsewhere may eventually produce pressure erosion of bone (Fisk, 1949). If this is suspected in cysts of the lateral cartilage, it is

FIG. 657.—Air arthrography showing an exostosis and a thickened cystic cartilage overlying it (re-touched). (*Case* 9.)

important to exclude the presence of an abnormally deep groove for the popliteus tendon. (*Fig.* 656.) The cyst may be present in an unusual site owing to tracking of the contents, as in the case previously mentioned where the cyst appeared above and to the side of the patella. When effusion is present it is usually small, and only occasionally is recurrent swelling of the knee-joint one of the complaints. In no case has a large effusion been seen in which there has not been a definite history of internal derangement of the cartilage as well.

Differential Diagnosis. — Difficulty arises usually with a small cyst difficult to palpate or obscured by subcutaneous fat. The diagnosis frequently demands the exclusion of the following conditions :—

1. *Arthritis.*—Small marginal exostoses may be tender, and have some bursal development around them. These may be bilateral. The age of the patient, the more generalized disturbance of the joint, the presence of obvious arthritis clinically, and careful radiography will exclude this condition. Occasionally a solitary small exostosis will only be shown by oblique views of the tibial plateau and rarely an exostosis and cyst may coexist (*Fig.* 657). In the adolescent patient exostoses of developmental origin around the upper end of the tibia are easily recognized radiographically and though they are covered with a cartilaginous cap and a bursa, can usually be distinguished as arising below the joint line.

2. *A Tag of Torn Cartilage.*—Occasionally a long tag of torn cartilage passes into the space between the tibial plateau and the coronary ligament. Such a tag may simulate a small ganglion very accurately, and in the absence of a previous history of

FIG. 658.—Air arthrography showing a tongue of medial meniscus turned under the outer rim of the meniscus and lying over the edge of the tibial plateau.

trauma and recurrent incidents an exact diagnosis may be impossible, except by arthrography (*Fig.* 658).

3. *A Loose Body.*—A loose body may become caught over the joint line and if translucent may require arthrography to demonstrate it.

4. *Cysts of the Anserine and Other Bursæ.*—An effusion into the anserine bursa is usually large and the tendon of the semitendinosus can be felt crossing it. In one case a cyst of the medial meniscus presented itself in an unusual manner. The patient noticed a small swelling over the medial aspect of the joint for some months, with the characteristic symptoms of a cyst. On the day that he was to attend the cyst had disappeared with acute pain and the development of swelling and tenderness on the inner side of the knee. The anserine bursa was found to be distended and there was local warmth and acute tenderness. It appeared probable that a cyst of the medial meniscus had suddenly ruptured into the anserine bursa, with the production of acute bursitis, in the same way as calcified material in the supraspinatus tendon may rupture into the floor of the subacromial bursa. The condition was rapidly relieved by rest, and a cystic medial meniscus was subsequently removed.

Enlargement of the bursa between the fibular collateral ligament and the semilunar cartilage has been described (De Palma, 1948).

Distension of the subpatellar bursa may be mistaken for an anterior cyst, but is softer and appears on either side of the patellar tendon, under which cross-fluctuation can usually be obtained.

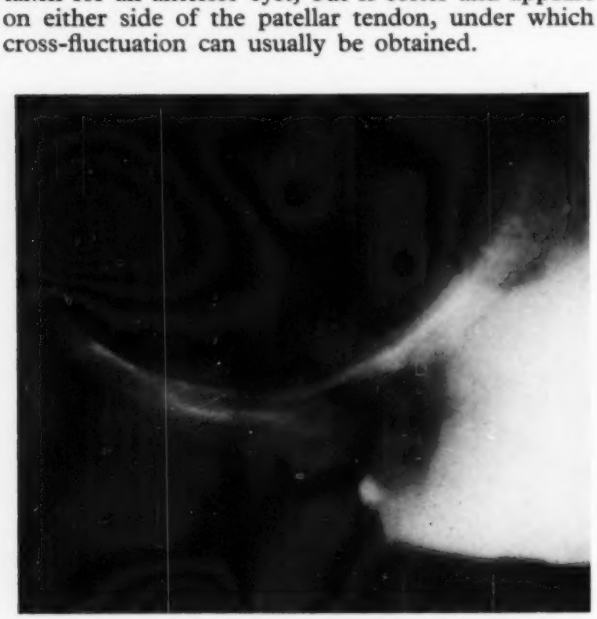
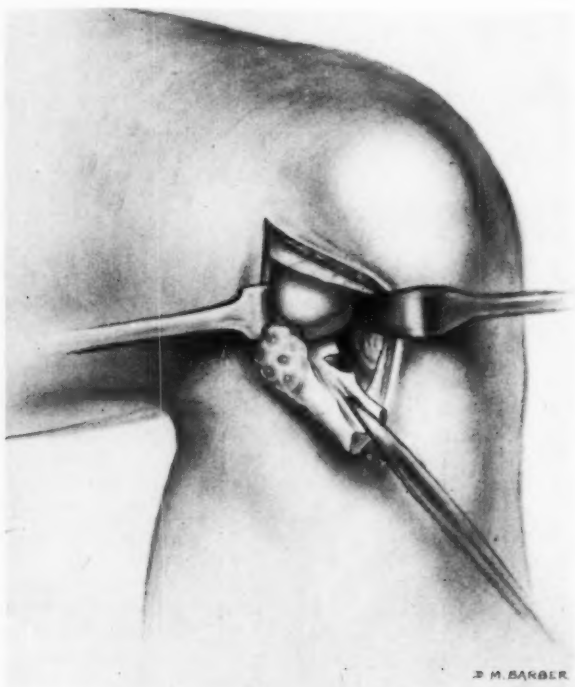


FIG. 659.—Air arthrography showing a torn lateral cartilage and cystic changes in the distended cartilage above the popliteal groove. (*Case* 18.)

5. *Tumours of the Subcutaneous Tissues.*—Fibroma, lipoma, neurofibroma, and sebaceous cysts may be mistaken on casual inspection for a cyst of the cartilage.



Air Arthrography of the Knee.—Experience with air arthrography in injuries to the meniscii suggested that it might be of value in the diagnosis of cysts. Its use has, however, proved to be very limited. This is due to the increased soft-tissue pressures around the affected meniscus which prevent the entry of air and reduce the relative contrasts on which a good quality air arthrograph depends.

Air arthrography may confirm a doubtful case of cystic development by showing an increased bulge in the peripheral shadow of the cartilage. Occasionally cystic spaces may also be seen in this shadow (*Fig.* 659), but if the cysts are large enough to be shown radiologically they are also large enough to be diagnosed clinically. Air arthrography may also be useful in differential diagnosis of displaced tags of cartilage (*Fig.* 658) in confirming the presence or absence of tears pre-operatively (Bonnin and Boldero, 1947). An unusual case is illustrated (*see Fig.* 657) in which the cystic spaces were shown to overlie the bulge produced by a marginal exostosis, thus assisting materially in the differential diagnosis.

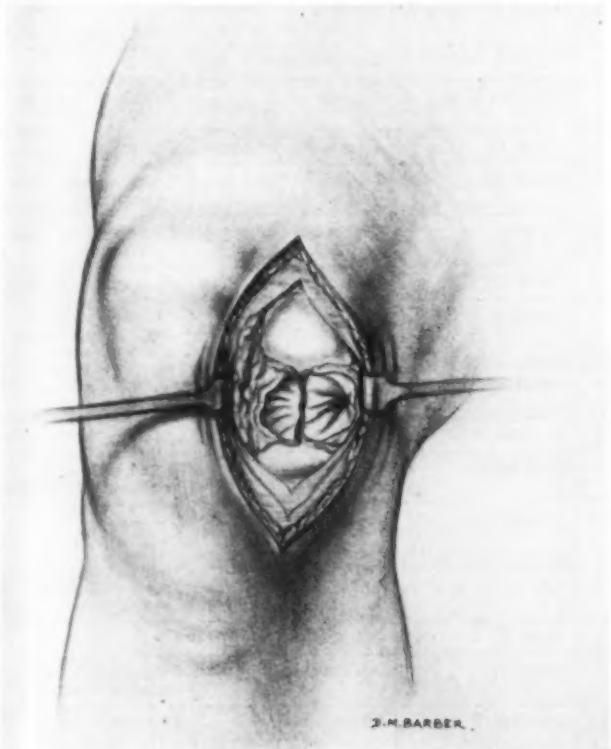
Treatment.—When the disability is slight, the patient may prefer to leave things as they are. The rate of growth or the possible subsidence of the cyst cannot be foretold, though it can be said that once the cyst is present, slow development is most likely. Unless the meniscus is torn, no harm would appear to arise from postponing operation until the patient is convinced of its necessity.

Many surgeons have been tempted to try local removal of a cyst. Theoretical objections can be raised to this on the grounds that the cartilage is probably degenerate, that unexpected tears are common, and that complete removal of the cyst loosens the attachment of the posterior third of the cartilage and may make it liable to tears or displacement. The practical objections are even stronger. All surgeons who have tried local removal agree that rapid recurrence is the rule rather than

FIG. 660.—The anterolateral approach to a cystic right lateral meniscus. The anterior end of the meniscus has been cut off. The tear visible has been produced by traction, but a deep lamina split was found underlying this. (*Case* 2.)

the exception, and that it is more disconcerting to the patient than the original cyst owing to its rapid herniation through the capsule. Recurrence can be prevented only by excision of the cartilage, which either eradicates the origin of the cyst entirely or removes a stimulating factor responsible for its development. Complete excision of the cartilage through an anterior incision is therefore to be recommended (*Fig.* 660). It has been pointed out that as the cyst commonly protrudes behind the posterior border of the collateral ligament its complete removal without risk of damage to the ligament is often impossible. Experience shows that even if some portion of cyst is left behind in this situation it fibroses and new cyst formation ceases.

Occasionally extensive involvement of the cartilage or an associated tear so weakens the cartilage already more firmly bound down posteriorly than normal, that it cannot be pulled forward in one piece prior to detachment of the posterior horn. In such cases a posterior incision to remove the posterior horn is necessary and this also facilitates complete removal of the cyst. Some surgeons as a matter of routine prefer to make a curved skin incision long enough to allow access to the cartilage both in front and behind the collateral ligament, and with this technique complete resection of both cyst and cartilage can always be performed, though in my experience this is not essential, removal of the cartilage being the more important (*Fig.* 661).



Prognosis.—The prognosis after removal of the cartilage is uniformly excellent. As more damage has been done to the synovial membrane of the joint than during meniscectomy for a simple tear of the cartilage, there is an increased liability to post-operative hæmarthrosis, the recovery period is slightly longer, and any post-operative effusion is more persistent.

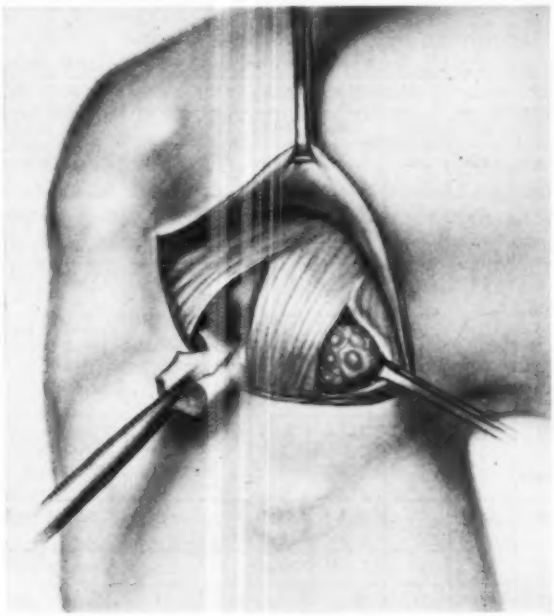


FIG. 661.—The combined approach to cartilage and cyst through a curved incision. For a cyst of the lateral meniscus.

FIG. 662.—A large anterior cyst of the right medial meniscus, an extension of which had previously ruptured into the knee-joint (*Case* 5.) The division across the cyst represents the line of section of the original incision.

CASE-HISTORIES

A summary of the histories of 29 cases involving 30 meniscectomies is given in *Table I.* All were proven by microscopy, with the exception of a few clinically obvious large cysts. Some unusual clinical

Table I.—CASE-HISTORIES OF CYSTS OF THE SEMILUNAR CARTILAGE OF THE KNEE-JOINT

CASE	AGE	SEX	SITE	TRAUMA	SYMPTOMS AND DURATION	TUMOUR, SIZE, AND SITE	OPERATIVE FINDINGS	COMMENTS
1	28	M.	R.L.	None	Triad 2 yr.	Small C	Extensive cysts	Extra posterolateral incision
			L.L.	Strain 3 yr. ago	Triad 3 yr.	Small C	Small tear post. horn	
2	21	F.	R.L.	None	Triad 1 wk.	Large C	Laminar split	
3	25	M.	R.L.	None	Triad 6 mth.	Medium C	No tear	
4	26	M.	L.M.	Crush of knee	Triad 3 yr.	Medium C	Torn anterior horn	Knee squeezed between barrels
5	45	M.	R.M.	None	Tumour only 3 yr.	Large A recurrent	No tear	Presented at anterolateral border of patella. Subsided once
6	32	M.	R.M.	G.S.W. thigh	Triad 6 wk.	Medium posterior	Local excision. Recurrence. No tear	Cure with complete meniscectomy
7	46	F.	R.L.	None	Triad 1 yr.	Small C	Parrot-beak tear	Moved after first operation
			L.L.	Old fractured ankle	Triad 1 yr.	Small C	Not operated on	
8	28	M.	R.M.	Direct kick 10 yr. ago	Triad 6 wk.	Medium A	No tear	Extensive anterior cysts
9	45	M.	L.L.	Kick 20 yr.	Triad with incidents 4 yr.	Medium P	Parrot-beak tear	Calcification in cartilage. Local exostosis. Cysts shown by arthrography
10	24	M.	R.L.	Blow 6 mth. and 7 d. ago	Triad 6 mth.	Medium C	No tear	Small effusion
11	37	F.	L.M.	None	Tumour only 6 mth.	Small A	No tear	Unilocular cyst
12	24	M.	R.L.	None	No night pain 2 wk.	Small C	No tear	
13	34	M.	R.L.	None	Triad 6 yr.	Small C	No tear	Recurrent attacks of triad symptoms at 3-mthly. intervals
14	28	F.	R.L.	Strain 5 yr. ago	Triad, but no night pain 6 wk.	Medium C and A	No tear	
15	34	M.	R.M.	Strain 6 mth. ago	Triad 8 wk.	Small C	No tear	
16	32	F.	R.L.	None	Triad 3–4 yr.	Medium C and A	No tear	Recurrent attacks of triad symptoms
17	52	M.	L.M.	None	Triad 6 mth.	Small C	Bucket-handle tear	Also mild O.A. of knee
18	49	M.	L.L.	None	Triad. No night pain. 8 yr.	Small C	Laminar tear and parrot beak	Cysts shown in air arthrograph
19	28	M.	R.L.	None	Triad. No night pain. 8 wk.	Large C	Parrot-beak tear	Post-operative wound infection
20	48	M.	R.L.	None	Triad 8 wk.	Small C	Parrot-beak tear	
21	42	F.	R.L.	None	Triad 1 yr.	Large C	Parrot-beak tear	Extensive cysts, fibrosis, and xanthomatous change
22	25	M.	L.L.	Strain 1 yr. ago and 1 mth. ago	Triad. No night pain. 1 mth.	Small C	No tear	
23	33	M.	R.L.	None	Triad 10 d.	Medium P	No tear	
24	36	M.	L.L.	None	Triad 18 mth.	Medium C	Parrot-beak tear	Extensive capsular fibrosis, and exostosis
25	32	M.	R.L.	None	Tumour 2 yr. Triad recently	Medium A	Anterior horn tear	
26	27	M.	R.L.	Blow 3 mth. ago	Tumour 6 mth. Triad in last 3 mth.	Small C	Parrot-beak tear	Soft-tissue bulge over meniscus shown by arthrography
27	50	F.	L.L.	None	Triad 1 yr.	Small C	No tear	
28	30	M.	R.L.	Injury to ankle 8 yr. ago	Triad 8 yr.	Large A	No tear	Recurrent attacks of triad symptoms
29	30	M.	L.L.	Doubtful injury 10 yr. ago	Triad. Cyst present 3 yr.	Medium P	Oblique tear	Recurrent attacks of triad symptoms

C, Central, the common site at junction of posterior and middle third; A, anterior to this; P, posterior to this.

Summary

Thirty-one cysts, 30 meniscectomies. Average age 31 years. Seven medial and 24 lateral meniscectomies.
Twenty-two male and 7 female cases. Twenty cysts at the classical site, 7 anterior and 4 posterior.
Fourteen cartilages torn, 8 being "parrot beak" tears.

findings have already been mentioned, but a few cases call for further comment.

Case 5 is interesting as the patient probably had a rupture of a cyst into the knee-joint with temporary alleviation of his complaints. Two swellings on the medial and upper borders of the patella, one above the other, were noted in 1946. They varied considerably in size during the next three years, but recently had become steadily larger. Four days before being seen, the main cyst on the upper border of the patella had disappeared suddenly with a tearing sensation and there had been persistent pain in the knee-joint since.

On examination there was a slight increase in synovial fluid and medial to the patella a palpable thickening of the soft tissue in which a small cyst was present. In view of the distance separating the swelling from the medial meniscus it was considered that a ganglion of the quadriceps expansion was present and that this had ruptured into the knee-joint.

The case was treated conservatively with a firm bandage and quadriceps exercises, and the patient recovered satisfactorily, but two months later the cystic swelling recurred and steadily increased in size.

At operation, extensive cystic degeneration of the medial meniscus was found, commencing at the centre point and extending throughout the anterior horn and up into the sub-synovial tissues beside the patella. Excision of the involved tissue and the meniscus was performed. There was no evidence of injury to the cartilage. (*Fig.* 662.)

In *Case* 6 the cyst, being posterior to the femoral condyle, demanded an approach through a posterior incision. When exposed it appeared to be totally separated from the meniscus, and, in spite of previous experiences, local excision only was carried out. Recurrence took place within three months and total meniscectomy was necessary for a complete cure.

This series demonstrates :—

1. A peculiarly high incidence of involvement of the medial meniscus.
2. The less usual bilateral involvement.
3. The inconstant relationship to trauma.
4. The absence of a history of injury in many cases in which a tear is found at operation.
5. The disproportionate incidence of ' parrot beak ' tears.
6. The occurrence of attacks of disability rather than continued disability in some cases.

SUMMARY

Cysts of the cartilage of the knee-joint are similar to ganglions elsewhere but show a greater tendency to recur after inadequate removal. They are an active proliferative lesion rather than a degenerative one.

Trauma is a precipitating factor in about one-third of the cases ; a history of minor or recurrent trauma is associated with a cyst in another third, and in the remaining third there is no history of injury and no operative evidence of injury to the cartilage. The relationship of a torn meniscus found at operation to the history of trauma is inconstant, suggesting that the cyst may contribute to the formation of a tear.

Cysts of the meniscii present a triad of features : pain after exercise, relieved by rest, but often worse at night ; the presence of a cystic swelling over the joint line ; and acute localization of pain and tenderness on pressure on the joint line.

A small number of cases are bilateral and these involve the lateral cartilage.

In unilateral cases the medial cartilage was involved more frequently than the lateral cartilage, and the incidence of its involvement is probably higher than that usually given (1–6).

Local removal of the cyst is followed by recurrence.

Complete removal of the cartilage and most of the cyst is an effectual cure.

I am much indebted to Mr. K. I. Nissen for his helpful advice and criticism in the preparation of this paper.

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HÆMANGIOMA OF THE SPLEEN

RELATION TO OTHER CYSTIC TUMOURS. CASE REPORT OF GIANT CAVERNOUS HÆMANGIOMA

By RODNEY SMITH and N. F. C. GOWING, London

Study of relevant literature brings the conclusion that hæmangioma of the spleen is a condition of considerable rarity. Several authors have discussed the tumour under the general heading of 'splenic cysts', of which Fowler (1940) reviewed 137 cases that had appeared in the literature up to 1939. Since that date other examples have been reported (McClure and Altemeier, 1942; Gallagher and Mossberger, 1942; Harmer and Chalmers, 1946). Apart from the solitary cysts included in this classification, occasional examples of multiple cysts are encountered in association with congenital polycystic disease of the kidneys, pancreas, and liver. In a recent review of polycystic disease of the kidney Rall and Odel (1949) reported multiple cysts of the spleen in 2 per cent of their cases coming to autopsy.

Solitary splenic cysts may be broadly classified into :—

1. Parasitic cysts—hydatids.
2. Non-parasitic cysts :—
   a. Dermoids and epidermoids.
   b. Hæmangiomata and lymphangiomata.
   c. 'False' cysts.

Hydatid cysts will not be further discussed. The cysts are designated 'false' if there is no demonstrable epithelial or endothelial lining. They form an indefinite group, for it is clear that such a lining, originally present, may become lost as a result of degenerative changes so that correct pathological classification becomes impossible. Nevertheless, it appears certain that many false cysts are without a lining from their inception, and the aetiological importance of injury and hæmorrhage into the spleen has been stressed by several authors. Tamaki (1948) states that a history of trauma is available in a high proportion of hæmorrhagic false cysts. It has also been pointed out that such cysts are relatively common in West African natives, amongst whom malaria and splenomegaly are widespread (Harmer and Chalmers, 1946). The role of embolism and thrombosis in the genesis of false cysts is discussed by Dabrzaniecki (1930).

Dermoids and epidermoids appear to be rarer than other varieties of non-parasitic cyst. Dermoids presumably take origin from embryonic cells segregated during early life, and epidermoids may have a similar pathogenesis. Bostick and Lucia (1949), however, in describing an epidermoid cyst of the spleen in a man of 20 years, suggest that the epithelial lining may arise by metaplasia of mesenchyme. They therefore propose the term 'metaplastic mesodermal cyst' for this variety, but the simple descriptive name 'epidermoid', which commits us to no special aetiological standpoint, would still seem preferable.

In common with the majority of vascular 'tumours', the hæmangiomata and lymphangiomata of the spleen are to be regarded as malformations of congenital origin rather than as true neoplasms. As would be expected, a considerable proportion of cases have angiomatoid malformations in other organs as well as the spleen, and it is perhaps of interest to note that several early papers (quoted by Dowd, 1915) reported angiomata of the spleen with 'metastases', in the liver and elsewhere. In view of their probable origin in very early life, the age incidence of the angiomata of the spleen calls for comment. Although a few examples have been described in infancy, the majority of the reported cases have been in adults. It must be presumed that the spleen enlarges slowly over the years until it reaches a sufficient size to produce symptoms. Such an enlargement is not produced by cell-division in a neoplasm, but may result from : (*a*) Inflammatory swelling; (*b*) Progressive dilatation of the cavernous spaces; (*c*) Thrombosis in some channels leading to engorgement of other parts of the angioma; (*d*) Canalization of previously uncanalized vasoformative tissue included in the malformation.

In most instances, and in the case here reported, factors (*b*) and (*c*) are probably the most important. By the time splenectomy is performed such changes may be so extensive that pathological diagnosis is rendered very difficult. Many sections may have to be examined before typical cavernous spaces lined by epithelial cells are found.

CASE REPORT

W. W., a man of 50, was admitted to a hospital on the outskirts of London after he had had a severe hæmatemesis. He was successfully treated by conservative means, receiving a total of eight pints of whole blood by drip transfusion. Meanwhile physical examination had revealed a very large mass in the upper abdomen. The nature of this seemed obscure and when he had completely recovered from his hæmorrhage he was transferred to St. George's Hospital for further investigation and treatment.

On Admission.—He was a powerfully built man and showed no signs of recent severe loss of blood. His general condition appeared to be excellent and the only abnormal physical signs were related to the mass in his abdomen. This was a smooth, tense, cystic swelling occupying the whole of the epigastrium and centred to the left of the midline. Its lower margin was below the level of the umbilicus and the upward extension had caused such elevation of the left leaf of the diaphragm and mediastinal shift that the apex beat was palpable just medial to the right nipple. Radiographs (*Figs.* 663-664) showed the margins of the tumour clearly and also areas of calcification in its centre (*Fig.* 664 A). Examination with a barium meal showed gross displacement of the stomach forwards and to the right (*Fig.* 664).

A diagnosis was made of a cyst of the spleen or tail of the pancreas. Naturally the patient was asked how long he had had this enormous lump in his belly, but he expressed astonishment, saying that he had never noticed anything wrong.

At Operation.—After induction with pentothal, anæsthesia was maintained with nitrous oxide and oxygen, relaxation being obtained with curare.

The abdomen was opened by a long left paramedian incision and the anterior surface of an enormous tense cyst of the spleen presented, covered by a 'capsule' of

compressed splenic tissue. An onlooker at this point suggested that in order to deliver the tumour from the abdomen it would clearly be necessary first to puncture it and evacuate the contents. This temptation was resisted, as it was not considered desirable to have first-hand experience of the unfortunate end to the operation

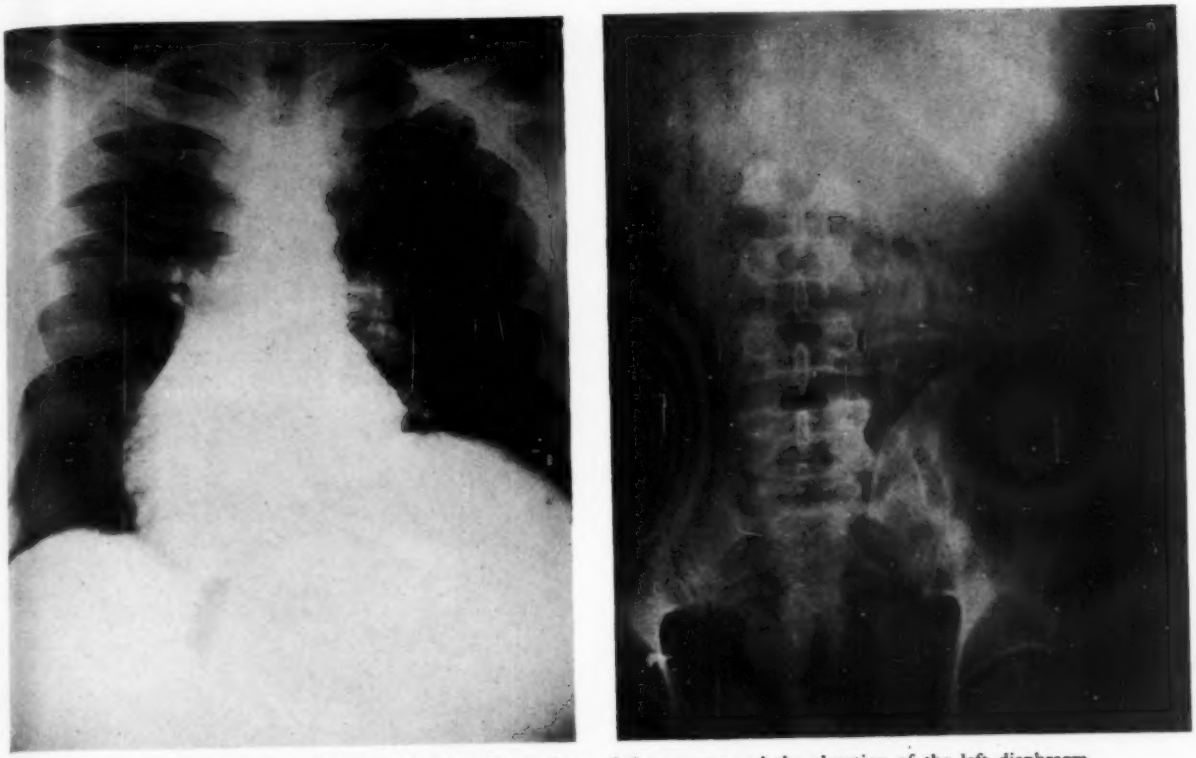

FIG. 663.—Soft-tissue radiographs showing the outlines of the tumour and the elevation of the left diaphragm.

A B

FIG. 664.—A, Barium meal showing the displacement of the stomach forwards and to the right. In B, calcification in the tumour can be seen.

described in *The Citadel*. The incision was enlarged by a transverse extension cutting across both rectus muscles, and it was then possible to deliver the enormous splenic

A

FIG. 665.—Gross appearance of specimen.

mass from the abdomen. The pedicle was easily secured and splenectomy was a simple procedure. The abdominal wall was repaired with stainless steel wire.

Convalescence was uneventful and the patient was discharged to a convalescent home after twelve days, having been ambulant from the day after operation. He reported for routine examination three months after his operation in excellent health and exhibiting no weakness of his abdominal wall. He had resumed his occupation as a meat porter, but was at the moment out on strike.

PATHOLOGICAL REPORT.—

Macroscopical Appearance.—The splenic mass was roughly spherical in shape but somewhat flattened antero-posteriorly. It weighed 8 lb. 12 oz. The notched

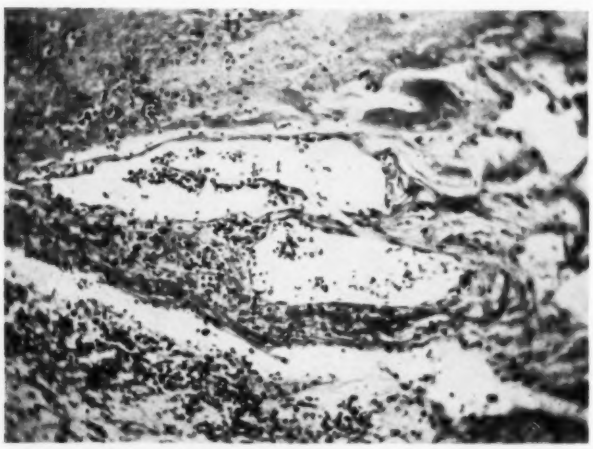

FIG. 666.—Microscopic appearance of the tumour. Low power. (H. and E.) One of the few areas sufficiently free from necrosis and thrombosis to show vascular spaces lined by endothelium.

inferior border of the spleen could still be seen as a sharp ridge (*Fig.* 665, A, B). On cut section a narrow rim of compressed splenic tissue was apparent beneath the thickened capsule. The main bulk of the tumour consisted of dark red material with irregular paler areas and scattered foci of calcification (*Fig.* 665, C).

B

C

Histology.—Throughout the greater part of the angioma there was extensive thrombosis in the vascular channels, with destruction of the endothelium and partial organization. However, the outlines of the vascular walls could still be shown clearly in sections impregnated for reticulin, and a careful search revealed spaces lined by an intact endothelial layer. The appearances were those of a cavernous hæmangioma of the spleen in which widespread thrombosis and degenerative changes had occurred. (*Fig.* 666.)

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INJURIES TO THE LARGE LYMPH-DUCTS

By A. LEE McGREGOR, Johannesburg

The lymphatic system is rather taken for granted. Many important functions are ascribed to it, yet it is not normally in evidence. Arteries are felt, veins are seen, and even filaments of the sympathetic nervous system are becoming familiar to the surgeon round the bile-ducts and elsewhere, but lymph-vessels are rarely noted. Perhaps the only time the practitioner sees them is when they present in the skin as the red streaks of lymphangitis. The medical student is fortunate if he sees the thoracic duct when doing his dissecting course. Despite the fact that lymph-vessels are developed from and accompany veins, peripheral lymphatics are not seen at operation except to the trained eye in a gross condition such as advanced breast cancer, when infected lymphatics may be seen where these structures converge on the termination of the axillary vein. Small blood-vessels may bleed, but, as lymph is a colourless fluid, it is not seen even when lymphatics are extensively divided in procedures such as radical mastectomy and groin clearance. The only lymph-vessels commonly seen are the lacteals in relation to the small intestine.

The practised surgeon is wary in dissections above the inner end of the collar-bone when working in the region of the thoracic or right lymph-duct. The former is in close relation to the œsophagus when this structure is being mobilized by blunt dissection behind the aortic arch, but its injury in this or any other situation is of the nature of a surgical rarity.

As a result of this lack of apparentness of the lymphatics, the system is a somewhat nebulous one, and the surgeon assumes, usually correctly, that it will look after itself, as indeed it does in the majority of cases. Just how correct is this assumption?

Before dealing with this question it is pertinent to ask what are the results of injury to large lymph-ducts, which in turn leads to an inquiry into the functions of the lymphatic system.

THE FUNCTIONS OF THE LYMPHATIC SYSTEM

The importance of the system may be inferred from the knowledge that extensive damage to lymphocytes and lymphoid tissue results in death. The normal lymphoid tissue content of the body approaches 1 per cent (Drinker and Yoffey, 1941, a). The liver or brain is about 1½ per cent. The peripheral lymphatic vessels are so profuse that McMaster (1937) states that the skin cannot anywhere be punctured with a needle without tearing lymph-vessels. It follows that as the absorption of many foreign substances into the lymphatics is rapid, an injection into the skin is tantamount to an injection into the lymphatic system. The system is a closed one, the lymph capillaries having a wall of endothelial cells which may become so permeable that it is difficult to imagine that these channels are shut off from the tissue fluids by an actual wall.

Drinker and Yoffey (1941, b) say that the main reason for the development of the lymphatic system is the need for a mechanism to return to the blood-stream proteins which have leaked from the blood-capillaries; also other substances in the tissue fluids which are not absorbed by the blood-stream, e.g., particulate matter. The larger lymph-vessels have a muscle coat, are contractile, and are supplied with nerves. They are abundantly supplied with valves, giving rise to the well-known beaded appearance. Lymph-flow is much enhanced by normal activity of the part, be this voluntary, involuntary, or secretory, yet the lymphatic system takes no share in lightening the load when œdema occurs owing to pathological conditions such as cardiac failure. It has been stated (Abel, Hampil, Jonas, and Chalian, 1938) that the volume content of the lymphatic system is about the same as that in the blood vascular system, although this is not established.

Hodge, Shreveport, and Bridges (1948) give the composition of chyle as 60–70 per cent of the absorbed fat, 1–6 g. per cent of protein, with an average of 3–4 g. per cent; non-protein nitrogen, sugar, urea, and minerals similar in amount to those found in blood-serum. The calcium and cholesterin content is slightly lower than in blood-serum. Lymphocyte and eosinophil counts are much higher than in blood. The loss of chyle from a fistula may exceed 2000 c.c. in twenty-four hours.

The authors explain death due to persistent loss of chyle from the circulation as being the result of the loss of fat and proteins. This accords with the observations of others (Baldridge and Lewis, 1948) that it is impossible to maintain adequate serum-protein levels by dietary means when the thoracic duct is incontinent.

Neutral fats, fatty acids, and esters are absorbed by the lacteals, and transported by the lymphatic system. So, too, this system is said to play a part in the extrahepatic formation of globulin. Antibody formation has been ascribed to the system, and it is reported to play a subsidiary part in the destruction of red cells.

Lampson (1948) states that chyle is bacteriostatic and remarks on the rarity of empyema in chylothorax and the frequency of sterile cultures after repeated thoracentesis. It is generally conceded that the lymphatic system exerts a 'barrier' action or defensive role in infections. So far is this from being the case in malignant disease that the lymphatics actually facilitate the spread of the disease by supplying ready-made routes of extension, and each lymph-gland involved acts as an additional centre for growth of the neoplasm.

An important function of the lymphatic system is the continuous formation of lymphocytes, and Yoffey (1935–6) showed in the dog that the thoracic duct transmits 5078 million lymphocytes in 24 hours.

The lymphatic system has extraordinary powers of regeneration which must play an important part in preventing chronic œdema and elephantiasis. Drinker and Yoffey (1941, c) say: "it is often thought that ligature of the thoracic duct at the point of venous entrance accomplishes complete obstruction

and will result fatally. Nothing can be further from the truth. Ligation of the duct may cause temporary lymph stasis and even chylous collections in the peritoneal, pleural, and pericardial sacs, but ordinarily after a brief period of stasis, lymph begins to enter the circulation through collateral lymph-venous connexions. If both the thoracic and the right lymphatic ducts are tied, care being taken that all possible lymphatic branches are secured, lymph may be excluded from the blood-stream for a short time, but ordinarily complete blockage will be a matter of hours only."

The same authors cite the work of Blalock, Cunningham, and Robinson (1936), who ligated the superior vena cava in experimental animals to show that if appropriate venous stasis is added to ligation of the thoracic duct, then obstinate chylous effusions may occur into the great cavities of the body. It is thus a matter of great difficulty under conditions of normal health to block the entrance of lymph into the venous system.

Lymph may be excluded from reaching the blood by obstruction or loss to the exterior. It is with the latter condition that this communication is concerned.

LYMPH FISTULA

Judd and Nix (1949) reported 40 cases of lymph fistula from the Mayo Clinic. These were collected from the records of forty years—one case a year. They draw attention to the little that is known about the matter. Such fistulæ may be spontaneous or traumatic. Of the 18 cases of the former there were multiple openings in all the cases, and all but one were subdiaphragmatic in situation. There were 6 cases of chyluria. Other responsible conditions were congenital lymphœdema. The duration of the condition was as long as twenty-five years. In 10 cases the lymph was chylous or mixed, which is adduced as evidence of the retrograde flow of lymph. The fistulæ tended to spread rather than to heal. The fistulæ are always annoying and sometimes disabling. The authors stress the fact that fistulæ of clear peripheral lymph, such as may be seen in the neck, axilla, or groin, are often unrecognized as such and attributed to serous discharge. The protein content is lower than that of serum. The authors point out that spontaneous fistulæ are more refractory and difficult to deal with than traumatic ones.

The 22 traumatic fistulæ followed operation in different parts of the body and showed a tendency to close spontaneously. It is noteworthy that as far as can be gathered from the report, only one of these cases followed an abdominal operation and there were none reported in the thorax. One case followed saphenous vein ligature and the authors report a number of cases of other surgeons following this operation, notably 3 cases of Fishback which were followed by prolonged lymph leakage from the operative site.

CHYLOTHORAX

Florer and Ochsner (1945) quote a review by Dorsey and Morris (1943) of 58 cases of chylothorax due to rupture of the thoracic duct from trauma. The gravity of the condition is shown by a 50 per cent mortality in cases in which operation had not been done, while the mortality was 100 per cent in cases where surgery had been unsuccessful.

Lampson (1948) comments on the rarity of the condition and was able to collect only 69 recorded cases.

Non-penetrating trauma, particularly when associated with hyperextension of the spine, may cause rupture of the thoracic duct. The lesion is sometimes associated with fractures of the thoracic cage. In several of the recorded cases the violence producing the rupture was surprisingly slight, e.g., a moderate blow on the chest or a fractured collar-bone. The rupture is commoner on the right in closed trauma and on the left when due to penetrating wounds. Severance of the duct is followed by a characteristic syndrome. The patient has a fairly comfortable period of about four days, then there is the sudden onset of severe dyspnœa, pallor, cyanosis, and a rapid thready pulse. The condition is immediately relieved by aspiration of the fluid, only to reappear with its reaccumulation, which may occur within twelve hours. Emaciation occurs rapidly, with a progressive decrease in the total protein of the blood. Florer and Ochsner (1945), together with other writers, stress the gravity of the prognosis. Brown (1937) reported a case of traumatic rupture of the thoracic duct with bilateral chylothorax and chylous ascites. The patient died. Florer and Ochsner quote the interesting observation of Heuer (1929) that chyle may escape from the lymph system if pressure from without obstructs it. In such cases it is surmised that the chyle capillaries burst because of the raised tension in the system, thus allowing the escape of lymph.

Elliott and Henry (1917) stressed the need for microscopical examination of the fluid withdrawn from the thorax, and instanced the readiness with which a faulty diagnosis of empyema may be made.

Macnab and Scarlett (1938), amongst others, divide milky effusions into chylous and pseudo-chylous. The latter condition, they say, may be due to emulsified fat from cells undergoing fatty degeneration, but the opacity is mainly due to a lecithin-globulin complex held in suspension by inorganic salts. This is usually a complication of tuberculosis or malignant disease and does not involve the thoracic duct. The authors state, conforming to the views of others, that the prognosis of traumatic chylothorax is 'unquestionably grave'.

Whitcomb and Scoville (1942) reported severance of the thoracic duct during a Smithwick operation for hypertension. The divided ends were closed with silver clips. Despite this a chylothorax had developed and death ensued during the intravenous replacement of aspirated chyle.

Hodge, Shreveport, and Bridges (1948) cite 2 cases—those of Deansley (1903) and Harrison (1916)—where the divided cervical thoracic duct was successfully implanted into a vein. They go on to state that, except in its upper part where the collateral circulation is generous, ligation of the thoracic duct may be followed by rupture due to internal pressure and advise safer methods of dealing with the accident. They report a case of implantation of the divided thoracic duct into the vena azygos major.

Lampson (1948) mentions that under normal conditions the pressure in the thoracic duct is very small, but after ligation it may reach 35 cm. of water. He refers to the case of Peet and Campbell where the retropleural ligation of the thoracic duct consequent on surgical injury during bilateral splanchnicectomy was not attended with success. in the lower thorax for chylothorax following a bullet wound.

Harrison (1916) implanted the end of the divided thoracic duct into the external jugular vein. So grave a view did he take of interruption of the duct that he considered its ligature to be tantamount to ligature of the intestine. Shackelford and Fisher

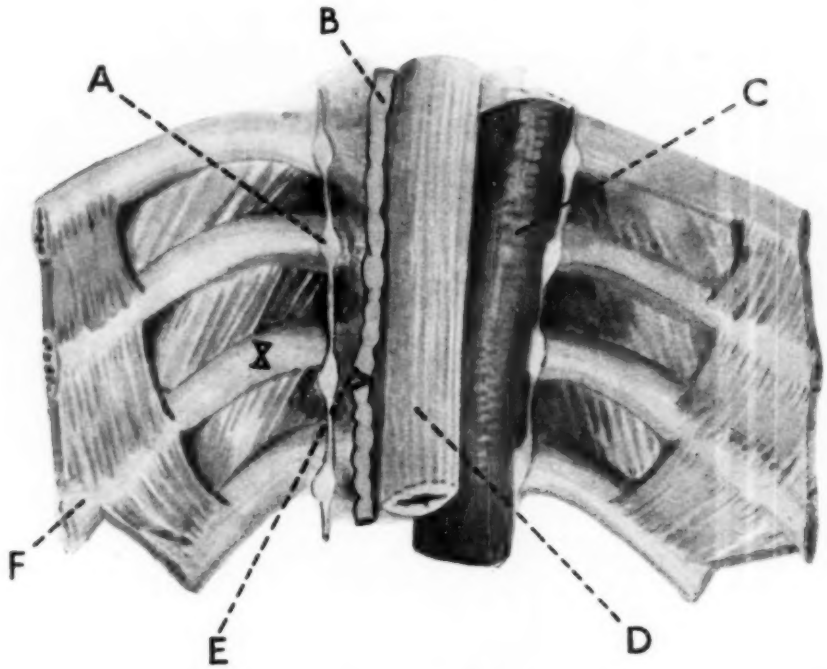

FIG. 667.—Showing the torn thoracic duct lying lateral to its usual situation. A, Sympathetic chain; B, Thoracic duct; C, Aorta; D, Œsophagus; E, Tear in duct.; F, Tenth rib.

The author reports an unusual case of chylothorax which appeared to result from a severe chronic cough. When conservative measures proved unsuccessful he was able to identify and ligature the leaking thoracic duct in the mediastinum.

Baldridge and Lewis (1948) state that the embryonic thoracic ducts are bilateral and have numerous cross anastomoses, and they stress the importance of the persistence of such channels following injury or obstruction to the main duct. The same authors quote the summary of Stuart (1907) of the anatomical variations of the thoracic duct to the effect that the usual description of a single channel throughout its course may be almost considered an abnormality as the duct so commonly branches and subdivides. These authors mention the important work of Doctor Charles Begg, who found that low down in the right side of the chest the thoracic duct is often within a few millimetres of the (great) splanchnic nerve. The authors report a case of chylothorax following a right-sided thoracolumbar sympathectomy for hypertension. Through a transthoracic exposure, and after division of part of the diaphragm, they were able to expose a tear in the cisterna chyli. This was dealt with by the ligature of all the ducts connecting with the sac and placing pleura and oxycel over the rent. Recovery was uneventful. Whiteside, Stewart, and Cuthbertson (1949) report successful ligature of the thoracic duct (1938) stated that although surgical ligature of the thoracic duct is physiologically compatible with life, it is an impracticable procedure.

TRAUMATIC INJURIES TO THE MAIN LYMPH-DUCTS

The following new cases are reported :—

Case 1.—**Hypertension** (*Case No.* 293).—On Oct. 11, 1949, at the Lady Dudley Nursing Home, Johannesburg, a first-stage right-sided thoracolumbar sympathectomy (Smithwick) was performed on Mr. P., a short, sthenic individual aged 54. The diaphragm had been divided and the lumbar sympathetic trunk cut below the second lumbar ganglion. It was being dissected free in an upward direction. As is usually the case in well-covered persons, there was considerable extrapleural fatty tissue, especially abundant around the posterior extremities of the intercostal spaces where the lateral chain of sympathetic ganglia is situated.

Whilst dissecting the tenth thoracic ganglion, from the region of the head of the tenth rib, a flow of chyle was noticed. After the completion of the neurectomy the area of the chylous leak was investigated. Without difficulty the two ends of a beaded lymph-duct were exposed (*Fig.* 667).

The distal end leaked milky fluid. Both ends were ligated with linen thread, care being taken not to strangulate tissue. The duct was 2 mm. in diameter and exactly resembled the beaded appearance whereby the thoracic duct is usually represented in text-books of anatomy. The

injured structure was considered to be the thoracic duct because of its size and vertical direction. It is noteworthy that it was situated lateral to the vena azygos major.

Convalescence was uneventful. Fourteen days later the second stage neurectomy was done.

The patient's convalescence was uneventful. He left the nursing home ten days after operation.

The sac removed was the cisterna chyli. It was noteworthy that it lay quite an inch lateral to the first lumbar vertebra, and that only a single entering and

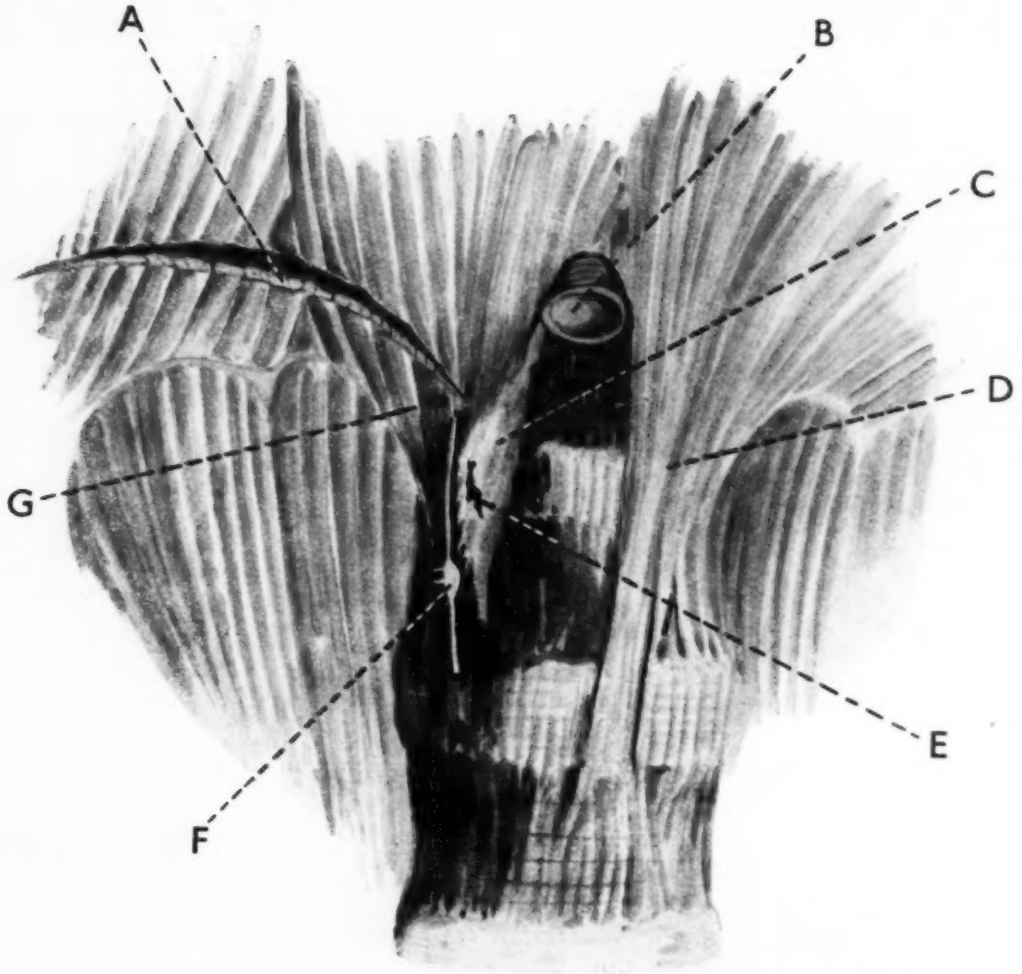

FIG. 663.—Semi-diagrammatic representation of *Case* 2, in which the cisterna chyli was torn. A, Diaphragm; B, Aorta; C, Cisterna chyli; D, Left crus; E, Tear in cisterna; F, First lumbar ganglion; G, Right crus, partly removed.

Case 2.—**Visceral Denervation** (*Case No.* 12).—The case was a young clerk referred by Mr. Hoffman, urologist, for denervation for intractable renal pain, consequent on pyelonephritis and ureteral strictures.

On the right side operation was performed. It was a sympathectomy of the Smithwick type as used for hypertension. After the lumbar chain had been cut and was being followed up through the divided diaphragm a flow of chyle was seen. After completion of the neurectomy the area of the leak was investigated. On the inner aspect of the right crus of the diaphragm, at the level of the first lumbar vertebra, there was displayed a flat structure 2 in. long by ½ in. wide. It exactly resembled an unstretched spider web and was extremely delicate in structure. A large lymph trunk connected with each of the two apices of the sac (*Fig.* 668). These trunks were 2 mm. across and not beaded. At the centre of the empty sac was a tear of the anterior wall ¼ in. across. A little chyle exuded. The sac was so tenuous in structure that it was considered not practicable to suture or ligature the tear effectually. It was therefore ligatured at each end and removed.

one departing duct made connexion with it. There were no other tributaries.

OTHER CHYLOUS LEAKS

In a large series of operations of the Smithwick type (not less than 400), lymph tissue has been occasionally noticed below the diaphragm when dissecting between the medial surface of the psoas major and the vertebral column in relation to the body of the second lumbar vertebra. Lymph and hæmolymph glands may be seen here and sometimes lymphatics of a millimeter or so in diameter. These cases are usually women and it is considered that the lymphadenopathy is of adnexal origin. It is usually possible to deal with the sympathetic trunk without damaging this lymphoid tissue.

This state of affairs is more commonly seen on the left than on the right, where the vena cava tends to obscure it.

An escape of chyle has been seen in several cases during dissection in this situation on the left side. Interestingly enough this has not occurred on the right side. The flow has never been copious, such as occurs when the thoracic duct or cisterna is torn, and no attempt has been made to secure the leak because there are no notably large lymph-ducts to the left of the lumbar spine. In no instance has there been reason to regret the non-closure of the leak.

Quite recently, during the retrograde removal of a chronically infected gall-bladder, and whilst separating the inner part of the organ from the liver through a somewhat thick layer of connective tissue, there occurred a momentary escape of milky fluid.

DISCUSSION

A review of the literature of lymphatic fistulæ makes it apparent that they are of two types: those due to disease and those due to trauma. The latter may be closed or the result of operative injury. The prognosis is better in the traumatic variety than in that consequent on disease; furthermore fistulæ resulting from operative trauma respond much more readily to appropriate treatment than such as follow closed injuries. Chylothorax is a condition of considerable gravity.

Whereas accidents involving spine or thoracic cage rarely do result in chylothorax, this condition is then situated on the right. The reason given usually is the fixation of the receptaculum chyli and thoracic duct by passage of the latter through the diaphragm. The injury arises in much the same way as rupture of the small intestine at points of fixation. Chylothorax may occur on either side of the chest as a result of injury during operation. This has become the case as a result of the frequency with which surgical procedures are now carried out in the vicinity of the great lymph-trunks. Thus operations on the sympathetic ganglionated chain, on the aorta, and on the œsophagus, all carry a risk to the great ducts.

Non-chylous lymph is lost in considerable quantity after extensive removal of lymphatic gland groups, e.g., radical mastectomy and groin clearance. For that reason drainage is necessary after these operations. The average amount of drainage after radical mastectomy is in the region of 250 c.c. during the first twenty-four hours. It may be lessened by pressure. That is why reasonable tension on the skin-flaps after mastectomy leads to better healing than redundant flaps. Lymph capillaries are sealed by the tension. This result cannot be obtained after a radical groin clearance as a cavity under the skin cannot be avoided. Thus such wounds discharge clear lymph for some weeks. The patient is little the worse for this fluid and protein loss. It is an entirely different matter when chyle escapes from the thoracic duct into the pleural cavity. The patient rapidly loses weight and life itself is in jeopardy. Should the condition only become apparent after operation as a chylothorax, action is none the less essential. Now the problem is much more formidable. Not only must the mechanics of the thorax be maintained in physiological balance, but so must the patient's metabolism. Repeated tappings may result in healing of the leak, but often enough the pleural cavity continues to fill with chyle and operation becomes imperative if life is to be saved.

PRINCIPLES

The BRITISH JOURNAL OF SURGERY was first published in 1913. A search reveals but a single article devoted to the thoracic duct in the thirty-nine years which have passed since the inception of this great instrument for the expression of surgical opinion. From this fact is appreciable how rare is the condition and how little interest has been aroused by the great lymphatic conduits.

Writing in this journal in 1916 Harrison advised implantation of the surgically divided thoracic duct into a vein. So grave a view did he take of interruption of the channel that he considered it tantamount to ligature of the intestine. His views were in accord with authoritative opinion of the period. With the improvement in methods of anæsthesia and increasing surgical aggression, surgeons were compelled to become conscious of the main lymph-ducts.

Shackelford and Fisher (1938) stated that although surgical ligature of the thoracic duct is physiologically compatible with life, it is an impractical procedure. Then appeared rare cases of ligature of a divided duct, and although they remain few in number, there has accumulated a sufficient body of evidence to establish on a sound basis the principles governing the surgery of the large lymph-channels. These may be stated thus:—

The Laws of the Great Lymph-ducts.—

1. *Lymph is Life.—*

a. Experimentally it has been found all but impossible to cut off the lymph entry to the vascular system.

b. Lymph must be conserved or death ensues.

c. Any flow of chyle should be traced to its origin and appropriate action taken.

d. In relation to thoracic duct and cisterna, stopping the leak is obligatory. In other situations leaks are usually insignificant and if not readily prevented they may safely be left to look after themselves.

2. *The Large Lymph-ducts are not essential to Life.—*

a. Injury to cisterna or thoracic duct is only important in as much as lymph may be lost to the exterior.

b. The cisterna chyli may be removed without detriment to the organism.

c. The thoracic duct may be tied without harmful consequence.

d. Duct or cisterna may be situated away from commonly accepted positions.

e. The surgeon should be duct conscious.

3. *Chylothorax threatens Life.—*

a. It causes death by inanition and lowering of the blood-proteins.

b. It is amenable to surgery.

c. Operation should be undertaken if a brief trial of conservative measures fails.

Stopping the Leak.—Lymph has this in common with bile, that it does not clot. Therefore just as the stump of the bile-duct does not heal from within but from without, so, too, the lymph-trunk should be so repaired as to enable this to occur. The divided right border of the lesser omentum is

repaired after cholecystectomy so that it may organize against the ligatured end of the cystic duct. The ligature occluding the divided thoracic duct should be of unabsorbable material. It should not be tied so tightly as to strangulate tissue. The author considers silver clips unsuited for this purpose. Neighbouring tissue should be placed over the ligatured duct end. No drainage should be used.

SUMMARY

1. The lymphatic system plays a vital part in the physiology of the body.

2. Injury to the great lymph-ducts is a very real danger attendant on modern surgery.

3. The correct treatment is recognition of the accident at the time of operation and the institution of appropriate action.

4. In conditions of health any large lymph-trunk may be ligatured with impunity.

5. Chylothorax is attended with a heavy mortality.

Subsequent to the completion of this paper a valuable contribution has appeared by Shumacker and Moore (1951). They report two infants operated on for Fallot's tetralogy, who developed traumatic chylothorax thirteen and fourteen days respectively after surgery. The wound was reopened in each case and chyle was seen flowing from a rent in the mediastinal pleura, above the aortic arch. It was not possible to find the injured duct. Sutures were fixed to the margins of the rent in the pleura and tied over gelfoam packed into the area. The subsequent course of the cases was uneventful. The authors make the useful suggestion of feeding cream to the patient several hours before operation to render the leak of chyle more copious and therefore easier to locate.

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PARTIAL SPONTANEOUS RUPTURE OF THE ŒSOPHAGUS

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SINCE Barrett (1946) wrote his review of the fascinating history of this subject at a time when no case of successful treatment had been recorded, advances in the investigation and treatment of intrathoracic disease have led to reports of 22 recoveries from this dangerous condition, including one by Barrett himself in March, 1946 (reported in 1947).

The tear may start as a rupture of the mucous membrane and only later extend through all layers to the pleural cavity or mediastinal tissues, and in one case recorded by Weiss and Mallory (1932) the patient died of hæmorrhage before all the layers had been penetrated; but we can find no record of a previous case in which the diagnosis has been made at this stage and treatment instituted before the perforation was complete; for this reason the present case is put on record. We wish to emphasize that if these patients are to be diagnosed correctly in the early stage and their lives saved, the possible cause of the symptoms must be borne in mind and the utmost value placed on radiological assistance in the diagnosis. Previous reports in the literature lay little stress on this method, but the advantages of the closest co-operation between the surgeon and the radiologist, or the screening of the patient by the clinician himself, are clearly obvious. There may be a fear of getting the patient to swallow barium if such a rupture is suspected, but provided the surgeon is prepared to act at once if barium is seen to penetrate outside the lumen of the œsophagus, there can be no danger in the method, whereas failure to use it may lead to fatal delay.

The use of the œsophagoscope, particularly in patients in whom a perforating upper abdominal lesion is suspected, may avoid an error in diagnosis, but except in the hands of the expert a small perforation in the œsophagus may be overlooked, and we believe that the use of screening when swallowing barium is a more valuable investigation.

CASE REPORT

Mrs. E. L., aged 67 years, housewife.

The patient was admitted to the Bristol Royal Infirmary on March 16, 1952, with the complaint of severe retrosternal pain. She had been well until the day of admission. At 8 a.m. she had her breakfast and experienced slight transient dysphagia. At 10.30 a.m., while eating a piece of swiss roll, she developed a sudden severe epigastric pain, colicky in nature, radiating up through the chest into the neck. Her doctor saw her at 11.15 a.m. Her colour was good, her breathing normal, and her pulse steady and slow. Her abdomen was soft, and no tenderness or guarding was found. She was given morphine, ¼ gr., and her pain was thereby eased. Her doctor saw her again at 1.15 p.m. At this time she was still getting severe spasms of colicky pain. Her colour was 'poor', her abdomen was now rigid and tender in the epigastrium, her pulse was regular, blood-pressure 190/90 mm. Hg, and her chest contained no abnormal physical signs. She had vomited some food and about 3 oz. of bright blood. As her pain was severe a further injection of morphine, ¼ gr., was given at 1.30 p.m. She entered hospital at 6 p.m., when she was found to be quite comfortable and of good colour. The neck and chest showed nothing abnormal. There was guarding and tenderness in the epigastrium. The blood-pressure was 190/96 mm. Hg and the pulse 108/minute; respirations 18 per minute and temperature 97·4° F. Severe retrosternal pain was produced whenever she swallowed a little water. The X-ray examination of lung fields was normal. At 12.30 a.m. on March 17, œsophagoscopy was carried out under general anæsthesia and a moderate amount of fresh bright-red blood was seen to well up into the œsophagoscope. At the level of the bifurcation of the trachea the œsophagus appeared to be narrowed by pressure from the left side. A hasty retreat was beaten at this stage as a dissecting aneurysm of the aorta was thought likely.

The three diagnoses considered were: (1) Spontaneous rupture of the œsophagus; (2) Dissecting aneurysm of the aorta; (3) Rupture of an œsophageal diverticulum.

Twenty-four hours after the onset of pain a barium swallow was performed. This showed no delay in the passage of barium down the œsophagus, but a persistent protrusion of the left wall of the œsophagus at the level of the left main bronchus (*Fig.* 669). The patient's temperature was 100·4° F. and her pulse-rate 100/minute. Her general condition was good, but swallowing was painful. An electrocardiograph showed some left axis deviation. Five days after admission the blood showed 6000 white cells per c.mm. A further barium swallow and barium meal showed a normal stomach and duodenum, but in the middle third of the œsophagus, commencing opposite the left main bronchus, the previous protrusion was seen to have increased in size and now had a waterfall effect suggesting an interstitial rupture (*Fig.* 670). There was some dilatation of the lower œsophagus.

In the light of these findings, an exploratory left thoracotomy was carried out on March 22. The patient was anæsthetized and œsophagoscopy was performed. As the instrument advanced to the level of the left main bronchus, a 'blob' of barium was seen to squeeze out of the left lateral wall of the œsophagus—like toothpaste from a tube, and following this there was further bright blood. Accordingly the patient was turned into the left lateral position and the chest opened. The pleural cavity contained a little blood-stained fluid but no

FIG. 669.—Barium swallow. 24 hours after onset of pain.

FIG. 670.—5 days after onset of pain.

FIG. 671.—12 days after operation.

FIG. 672.—3 months after operation.

adhesions. The mediastinal pleura overlying the descending aorta and mid-œsophagus was reddened, inflamed, and œdematous. The œsophagus was freed and tapes passed around it above and below this area. It was seen to be œdematous and inflamed and the muscle was friable, like wet blotting-paper, but no perforation had occurred. Accordingly it was returned to its bed—a tulle gras drain was put down to it and the chest closed with an underwater seal. The abdomen was then opened and a gastrostomy performed.

Gastrostomy feeds were begun next day. The tulle gras pack was removed from the chest five days later. She was maintained on penicillin for nineteen days, 500,000 units twice daily. Fluids by mouth were withheld until the twelfth post-operative day, when a repeat barium swallow showed some dilatation of the œsophagus and a thin incomplete septum at the site of rupture, but normal passage of barium into the stomach (*Fig.* 671). Accordingly feeding by mouth was resumed and the gastrostomy tube removed. The patient was discharged to a convalescent home, swallowing normally on the twenty-sixth post-operative day. An œsophagoscopy was performed as an out-patient one month later and a small sessile granular area on the mucosa of the left wall of the œsophagus was present at the level of the left main bronchus. Biopsy of this proved it to be granulation tissue only. A barium swallow on June 13 showed that there was some dilatation of the œsophagus above the diaphragmatic hiatus, but there was no evidence of the previous partial rupture (*Fig.* 672). The patient was swallowing normally and felt very well. Further œsophagoscopy seven weeks later revealed a normal œsophagus with no dilatation.

DISCUSSION

There are several features in the history and course of this case which are of interest. Contrary to some of the cases reviewed by Barrett in 1946, there was no history of vomiting or retching initiating the rupture. The trauma was extremely slight, namely, swallowing of a 'swiss roll', even allowing for some culinary defect in the roll. The patient remained comparatively well for six days after the initial trauma before operative treatment was instituted, this presumably being aided by antibiotic therapy. During this long delay repeated and careful examinations and various diagnostic procedures such as barium swallow, œsophagoscopy, and X-ray examination of lung fields did not reveal the necessity for operative intervention earlier. The diagnosis of rupture of the œsophagus was entertained from the first, but it was not until the second barium swallow gave the waterfall effect, and a residual 'blob' of barium was expressed from the œsophagus twenty-four hours after it was swallowed, that the diagnosis of intramural rupture could be confidently made.

Another unusual feature of this case was the site of rupture, viz., the middle third of the œsophagus at the level of the left main bronchus. In most of the recorded cases the site of the rupture has been adjacent to the diaphragm. The treatment was simple—viz., to provide drainage of the mediastinum in case a complete rupture should develop, to put the œsophagus at rest by withholding all food and liquids by mouth, and to maintain nutrition by a gastrostomy until a barium swallow showed that healing had occurred.

To date 22 cases of recovery following spontaneous rupture of the œsophagus have been recorded. The first such case is that reported by Fink (1947) of a man, aged 42 years, who in 1941 ruptured his œsophagus as a result of a violent attack of vomiting following alcoholic excess. He developed an empyema which was drained by rib resection. An œsophageal fistula resulted, which slowly closed without further treatment.

It is evident from perusing the case-histories of these 22 cases that they fall into two main groups, viz. :—

Group 1 : Those in which a correct pre-operative diagnosis was made, and a deliberate thoracotomy performed to repair the rupture.

Group 2 : Those in which an empyema developed, was drained, and subsequently an œsophageal fistula declared itself, so that the diagnosis of a ruptured œsophagus became evident by deduction instead of diagnosis. The fistula was then allowed to close of its own accord.

In Group 1 there are 13 cases, Barrett recording the first successful deliberate repair in 1946, to be followed by Clagget and Olsen in the following year. In 1949 Lynch records 3 cases treated successfully, and in the same year Clifton records 1 success and 1 failure, and in the English literature Scholefield records a recovery. In 1951 Carter, Alrich, and Drash record 2 successful cases, and in the same year Samson reviews all the known recoveries to date and adds 2 of his own. In this review Samson mentions a case treated by Allison which has not been recorded in the literature, but of which he has knowledge from a personal communication. In 1952 Bugden records a case operated upon within six hours of rupture that was discharged home fourteen days after operation.

In Group 2 there are 9 cases. The first of these is that by Fink already mentioned, which he recorded in 1947 although he operated on the patient in 1941. This was followed by 1 case reported by Moore and Murphy in 1948 and 1 case by Gardner in 1949. Samson, in his review in 1951, mentions 1 case by Overholt and 1 by Vestal of which he had knowledge from a personal communication, and records 2 cases mentioned by Graham in 1944. In 1951 Dunavant and Skinner record 1 case of drainage of an empyema with recovery, whilst in 1952 Kraft and Hughes record another. The present authors are particularly interested in Gardner's case because of its close resemblance to their own. Gardner's patient was a male, aged 30 years, who, while eating breakfast, felt a piece of toast irritate the œsophagus. This was followed by vomiting which caused retrosternal pain which increased in severity. Subsequent barium swallow gave a picture of a partial rupture of the œsophagus at the level of the eighth and ninth thoracic vertebræ, which closely resembles *Fig.* 669 in this communication. By contrast, however, Gardner elected to perform a posterior mediastinotomy and found a small peri-œsophageal abscess which communicated with an intramural abscess containing about 1 oz. of pus. He observed that this abscess communicated by a small pin-point perforation with the lumen of the œsophagus, into which he passed a probe. He noted that the condition of the œsophagus was similar to that recorded above, viz., firm and rigid and œdematous like a rubber hose. He made no attempt to repair the œsophagus but drained the mediastinum and fed

the patient by means of a Levine tube. It is evident that this case represents an intramural rupture which had finally perforated into the surrounding mediastinum and therefore had progressed one stage further than the case recorded in this paper. It is of interest that in both cases the trauma was minimal, viz., swallowing a piece of toast and a piece of 'swiss roll', and the rupture occurred in the middle third of the œsophagus in contrast to the usual site just above the diaphragm.

SUMMARY

1. A case of partial spontaneous rupture of the œsophagus, successfully treated, is recorded. The value of a barium swallow is stressed.

2. Twenty-two cases of spontaneous rupture successfully treated have been found in the literature to date. These have been divided into two groups according to whether deliberate thoracotomy and repair of the rupture was performed or merely drainage of an empyema.

3. The close similarity between the case of Gardner (1949) and the one recorded in this communication is noted.

4. No effort has been made to review the whole subject from the historical aspect, symptomatology, diagnosis, and treatment, because this has already been completely covered by Barrett in 1946 and subsequent writers.

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LATERAL DUODENAL DIVERTICULA

A REPORT OF TWO CASES

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THERE is an extensive literature dealing with the subject of duodenal diverticulum. An examination of the reviews and case reports discloses that nearly all duodenal diverticula are located within the concavity of the duodenum, in relation to the head of the pancreas. Horton and Mueller (1933) examined 141 specimens at autopsy. In all of these the diverticula were situated on the concave border of the duodenum, and 86 per cent were related to the main or lesser pancreatic ducts. The only record of diverticula on the lateral aspect of the duodenum is that of Weintraub and Tuggle (1941), who reviewed a series of cases identified radiographically. Of 349 diverticula, 17 (5 per cent) were located on the convex side of the second part of the duodenum. They do not give any detailed description of these and there is no report of their confirmation at operation or autopsy; it is therefore considered justifiable to report the following two cases.

CASE REPORTS

Case 1.—William A., aged 58 years, had suffered a good deal of abdominal pain from the time of the 1914-18 war. It was not, however, of sufficient severity to interfere with his work as a dentist. In 1935 he had a small melæna and was admitted to hospital. At this time there was radiological evidence of a duodenal ulcer, but no comment was made of a diverticulum (*Fig.* 673). This was first noticed on a barium meal which was done in 1939 because of recurring abdominal pain. In 1947 he was re-admitted to hospital, now aged 70 years, for further investigation of abdominal pain which had troubled him more or less continuously since 1935.

Laparotomy, performed at Guy's Hospital by Mr. Grant Massie on May 8, 1947, disclosed an active duodenal ulcer. The diverticulum was easily located on the lateral aspect of the second part of the duodenum. It was very thin-walled and communicated with the duodenum through a neck of about 1 cm. diameter. The diverticulum was invaginated and posterior gastrojejunostomy performed. He has remained in good health since the operation.

Case 2.—Alfred T., aged 50, a civil engineering foreman, was seen in January, 1948, complaining of attacks of epigastric pain associated with vomiting occurring every month and lasting two to three hours. The pain was relieved by vomiting, alkalis, and belching, and in the intervals between the attacks the patient was perfectly well. Barium meal examination showed a duodenal diverticulum on the lateral wall of the second part of the duodenum (*Fig.* 674). No evidence of peptic ulceration was present. Physical examination at this time showed no abnormal physical signs. The patient was treated medically with magnesium trisilicate, which he found relieved his pain during the attacks. During the next eighteen months the patient complained of nine further attacks, pain now passing between his shoulder-blades as well as being epigastric. Marked flatulence and vomiting, together with anorexia, were present during the attacks, but during the intervals the patient still felt perfectly well. Loss of weight of 21 lb. had occurred in this period of eighteen months. Physical examination

again showed no abnormality. The patient was admitted to Bristol Royal Infirmary in November, 1950, for operative treatment.

On laparotomy by Mr. J. H. Peacock a duodenal diverticulum was found on the lateral aspect of the second part of the duodenum opposite the entry of the common bile-duct. (*Fig.* 675.) The diverticulum passed laterally and slightly upwards, and was surrounded by a few adhesions. No evidence of peptic ulceration, pancreatitis, or diaphragmatic hernia was observed. The diverticulum was excised and the defect in the duodenum closed transversely in two layers. Post-operatively the patient made an uneventful convalescence.

FIG. 673.—*Case* 1. Radiograph showing evidence of duodenal ulcer, but no diverticulum.

FIG. 675.—*Case* 2. Photograph taken at operation.

A year later he was seen again complaining of the same symptoms. A radiograph disclosed that there was an ulcer on the lesser curvature of the stomach. He was re-admitted and a gastrectomy was performed.

GROSS PATHOLOGY.—The duodenal diverticulum was 2½ cm. deep, 2 cm. in diameter, with a moderately wide mouth connecting it to the duodenum 1¼ cm. across.

FIG. 674.—*Case* 2. Radiograph showing the diverticulum.

MICROSCOPICAL APPEARANCE.—This showed normal intestinal mucous membrane. The muscularis mucosæ was complete, but the muscle coat was only seen at the mouth of the diverticulum. Brunner's glands were poorly represented.

COMMENT

In both of these cases the unusual feature is the position of the diverticulum on the lateral, convex border of the duodenum. Both were characteristic in that they gave rise to no symptoms. *Case* 2 illustrates the danger of attributing symptoms to a duodenal diverticulum, for, although pain resulting from diverticulitis is said to occur, it must be very rare and the majority of duodenal diverticula are symptomless.

SUMMARY

Two cases of solitary duodenal diverticulum situated on the convex aspect of the second part of the duodenum are reported.

We wish to express our thanks to Professor R. Milnes Walker and Mr. Grant Massie for permission to publish these cases.

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NEURINOMAS OF THE CERVICAL SYMPATHETIC SYSTEM

WITH REPORT OF A CASE

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ALTHOUGH found in widely different parts of the nervous system these tumours have a predilection for certain sites, such as the roots of origin of the spinal nerves and the vestibular or cochlear divisions of the auditory nerve. They occur also in the sympathetic system and cases arising from its cervical part have been reported by Gibberd (1924), Callum (1949), Cullen and Monro (1952), and others.

The tumour of the cervical sympathetic is usually solitary and occurs on either side of the neck in men or women aged between 30 and 40 (some reported cases, M., 37; M., 32; M., 40; M., 42; F., 31; F., 42). Lying beneath the sternomastoid, it feels moderately firm and ovoid, is not tender, and can be moved laterally but not up and down. It has been mistaken for a tuberculous gland, a carotid-body tumour, or an aberrant thyroid, and a correct pre-operative diagnosis has only rarely been made. Horner's syndrome is not usually present before the tumour is removed, but is usually the aftermath of the operation.

CASE REPORT

HISTORY.—A married woman, aged 42, the mother of two healthy children, was referred by Dr. H. L. Coulthard because of a lump on the right side of her neck. Eighteen months previously, partial thyroidectomy had been performed in another hospital, and not long after her discharge she noticed the lump on the side of her neck "where the goitre used to be". She thought the lump had become smaller than it was at one time and stated that it ached when she was tired.

ON EXAMINATION.—An ovoid tumour could be felt deep to the sternomastoid on the right side of the neck. The appearance of the lump after thyroidectomy suggested that it might be a hypertrophied mass of thyroid tissue in relation to the right upper thyroid pole or even a lateral aberrant thyroid, but it did not move when she swallowed.

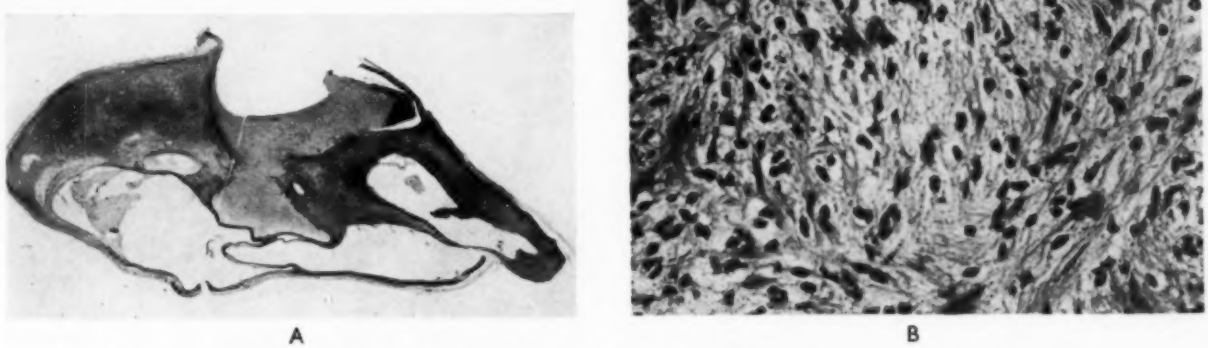
AT OPERATION (Feb. 5, 1948).—An incision was made in the line of the thyroidectomy scar, flaps containing the platysma were reflected upwards and slightly downwards, and the tumour was exposed by retracting the sternomastoid and separating it from its fascial coverings. The vagus nerve lay over the tumour, which was free from the jugular vein but closely related to the carotid artery. The tumour was seen to be partly cystic and to be connected to a cord running into the neck and containing some small cysts. The cord was divided beyond the cysts, the tumour removed, and the cord repaired. On the day following operation a Horner's syndrome was present on the right side.

FIG. 676.—Appearance of tumour (cystic neurinoma).

Professor Gough reported that the tumour was a neurinoma (Schwannoma or neurilemmoma) and was partly cystic (*Figs.* 676, 677).

COMMENT

These encapsulated tumours, which are often partly cystic, have been given a variety of names, e.g., neurofibroma, neurinoma, neurilemmoma, Schwannoma, peripheral glioma, perineural fibroblastoma. They are characterized histologically by a regimentation of cells, and apparently identical tumours have been described in fish of the snapper family by B. Lucké (1942), of Philadelphia. Believing their origin to be from neurilemmal cells, Willis



A B

FIG. 677.—Microscopical appearance of above tumour, cystic neurinoma of cervical sympathetic. A, Low-power, showing cystic areas (× 2·625); B, Higher-power, showing fibrillary structure (× 225).

(1948) favours the term neurilemmoma suggested by A. P. Stout (1935), of New York, and regards Verocay's (1910) term, neurinoma, as inappropriate inasmuch as this implies a tumour of the nerve-fibres. Current usage of this term might, however, justify its retention.

When readily accessible, as it often is, the neurinoma is a satisfactory tumour to deal with. If removed completely it does not recur, nor does its removal give rise later to local complications in the bed from which it was extracted. For these reasons it is the most promising of the intrathecal, extramedullary, spinal tumours if removed before conduction in the spinal cord has been completely destroyed (Rogers, 1948). Although the first spinal tumour to be removed successfully (Gowers and Horsley, 1888) was at the time regarded as a myxoma, it was almost certainly a neurinoma. This tumour was unfortunately destroyed in the museum of the Royal College of Surgeons of England by a high-explosive bomb dropped from an enemy aircraft on May 10, 1941, so that this cannot be verified, but the fact that the tumour was intrathecal and extramedullary and in part cystic is presumptive evidence.

Extrathecal spinal neurinomas are not always so satisfactory as the intrathecal tumours because complete removal is sometimes more difficult to effect. If the auditory neurinoma can be completely extirpated it does not recur, but here difficulty of access and the environment of the tumour frequently complicate the issue. Peripheral neurinomas, whether arising from somatic or sympathetic nerves, resemble the intrathecal spinal tumours in carrying an equally satisfactory prognosis in so far as they are readily accessible and can be completely removed.

SUMMARY

Neurinomas (neurilemmomas), which probably arise from neurilemmal cells, have sites of predilection in the nervous system and one of these is the cervical part of the sympathetic system. Preoperative diagnosis of these solitary tumours from the cervical sympathetic is rarely made. The tumour lies beneath the sternomastoid of a middle-aged man or woman, is mobile laterally but not vertically, and is not tender. It can be readily removed and does not recur, but Horner's syndrome may be an aftermath.

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FUNICULAR SUTURE AND FUNICULAR EXCLUSION IN THE REPAIR OF SEVERED NERVES *

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THE purpose of this paper is to discuss the advisability and practicability of performing funicular suture and funicular exclusion during nerve repair in an attempt to improve the chances of restoring the original pattern of innervation during regeneration and to reduce the wasteful escape of regenerating axons into the interfunicular tissue of the distal stump.

INTRODUCTION

The end-results of nerve suture are not such as to encourage complacency, for even in skilled hands the prognosis of repair remains unpredictable, while the results are often far from good and in many cases decidedly bad. Factors which complicate regeneration and adversely affect the quality of recovery after nerve suture have been detailed elsewhere (Sunderland, 1952). The most potent are those which result in the wasteful regeneration of axons and a distortion of the original pattern of innervation. With few exceptions, these are beyond the reach of therapy and the skill of the surgeon. Some encouragement, however, is to be gained from the fact that the peripheral nervous system possesses tremendous recuperative powers. If these are to be assisted to achieve a useful result, those factors restricting recovery which are subject to control should be distinguished from those which are not, because it is upon the former that efforts must be concentrated when repairing the nerve and when planning modifications of techniques and treatment. Unfortunately the former are few in number and are completely overshadowed by those which defy correction. Nevertheless they deserve careful consideration because they provide the only means of assisting regeneration.

RELEVANT ANATOMICAL FEATURES OF PERIPHERAL NERVES

1. It is uncommon for human peripheral nerves to be composed of a single funiculus. They are, on the contrary, usually composed of several funiculi which, by repeated division and anastomosis, engage in plexus formations along the full length of the nerve (*Fig.* 678). This leads to variations, from level to level, in the number and size of the funiculi (*Fig.* 679), while the funicular pattern is altered so

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rapidly that transverse sections taken more than a few millimetres apart fail to present precisely the same pattern (*Fig.* 680). Dissimilarities in the funicular patterns of the nerve-ends prevent the end-to-end apposition of corresponding funiculi at the suture line, so that during regeneration large numbers of axons grow into, and are lost in, the interfunicular tissue of the distal stump.

individual branches (Sunderland, 1945; Sunderland and Ray, 1948). This feature is illustrated in *Figs.* 681, 682.

The fibres representing individual branches at first pursue an independent course either as a single funiculus or as a compact group of funiculi engaging in plexus formations. Over this part of their course the fibres are consequently sharply localized, though

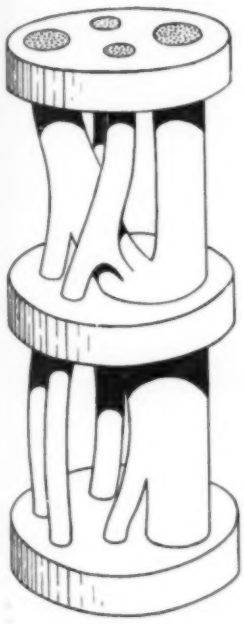

FIG. 678. — Funicular plexus formations leading to variations in the pattern and in the size and number of the bundles along the nerve.

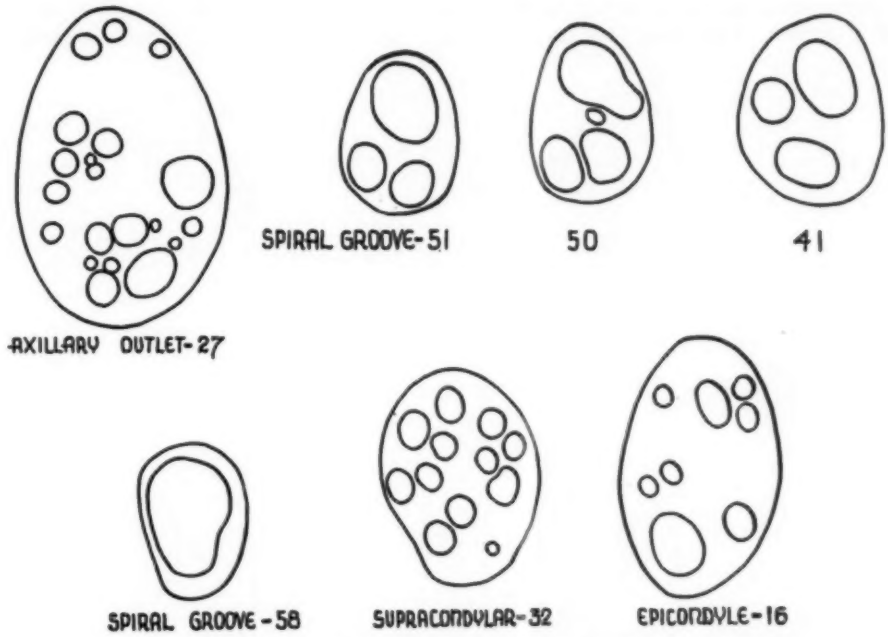

FIG. 679.—Transverse sections from a specimen of the radial nerve illustrating variations in the pattern and in the size and number of the bundles at seven different levels. The percentage cross-sectional area of the nerve devoted to the bundles is given with each section.

2. In addition to the variation in the number, size, and arrangement of the funiculi effected by plexus formations, peripheral nerves present individual, lateral, and regional differences and peculiarities as regards the proportion of the cross-sectional area of the nerve-trunk occupied by its component funiculi (*Fig.* 679). The epineurial tissue likewise varies in amount along the length of the nerve. Despite these variations there is normally a large amount of connective tissue separating the funiculi. This information has been detailed elsewhere (Sunderland and Bradley, 1949) and for the purposes of the present discussion it will suffice to state that the funiculi of human nerves are more compactly arranged in some regions than in others and that in most specimens the bundles are small and are widely separated.

The chances of the funiculi in the proximal stump being directed towards the interfunicular tissue in the distal stump are greatly increased when the funiculi are separated by a large amount of epineurial tissue (Sunderland and Bradley, 1949) and when the denervated bundles have atrophied (Sunderland and Bradley, 1950).

3. Funicular plexus formations also effect a regrouping and funicular redistribution of the component nerve-fibres as they are traced proximally from the point where they leave the nerve-trunk as they do not necessarily maintain the same quadrantic relationship as they ascend, since migration sometimes carries them obliquely through or over the surface of the nerve.

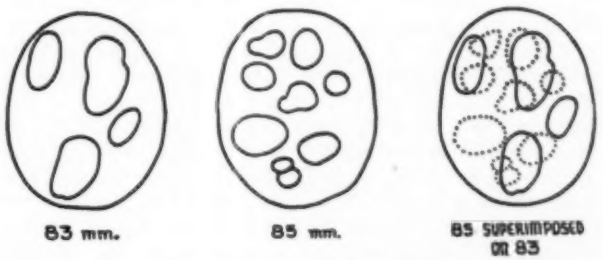

FIG. 680.—Transverse sections of a specimen of the radial nerve, taken 83 mm. and 85 mm. above the lateral epicondyle of the humerus to illustrate the dissimilarity in the funicular patterns produced by the funicular plexus formations occurring over the 2 mm. between the sections. When nerve suture is performed under these conditions, several of the funiculi of the proximal stump will be directed to the interfunicular spaces of the distal stump. Despite the dissimilarity of the funicular patterns, the chances of obtaining funicular apposition are increased when the bundles are tightly packed, but are diminished when they are widely separated.

The bundles of adjacent but independent bundle groups subsequently anastomose, thereby effecting a blending of the constituent fibres of originally distinct groups. An extension of this process ultimately

results in the widespread diffusion and blending of fibres from several sources. The scattering of fibres produced in this way occurs gradually, however, and over a short distance only a minor degree of intraneural shift is effected. It is the summation of changes at successive levels as the intercommunications are repeated which is ultimately responsible for the widespread intermingling and dispersal of fibres. The latter is achieved, therefore, only after the fibres have ascended considerable distances along the nerve. Thus the localization of any particular

1. Bundle groups representing individual branches first pursue an independent course along the nerve for variable distances above the site of branching. For this reason there are regions where the fibres representing some branches are localized on the surface of the nerve in separate bundle groups which may be accurately identified and isolated at the ends of a nerve severed at that level.

2. In its course a bundle group representing a branch system may alter its position in the nerve-trunk, without scattering or anastomosing with other

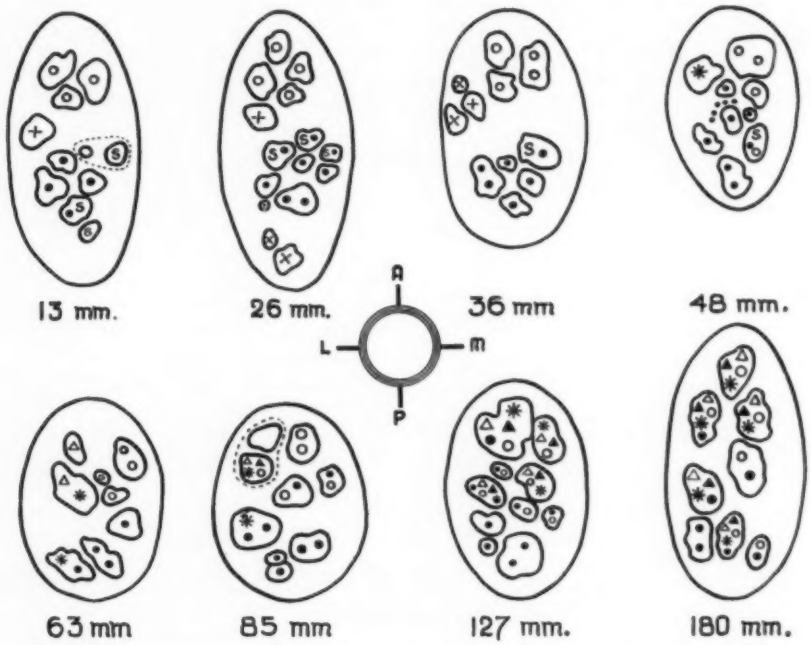

FIG. 681.—Diagrams of representative sections from a serially sectioned specimen of the radial nerve to illustrate: (*a*) the behaviour of a fibre system, e.g., the extensor carpi radialis brevis fibres, as it is traced centrally; and (*b*) the regrouping and funicular redistribution of the nerve-fibres which are effected by funicular plexus formations. The measurements give the level of the section, in millimetres, above the lateral humeral epicondyle. ○, Superficial radial; ●, Posterior interosseous; S, Supinator; +, Extensor carpi radialis brevis; ×, Extensor carpi radialis longus; ✱, Fibres for both the radial extensors of the wrist; △, Brachioradialis; ▲, Brachialis; A, P, L, and M, Anterior, Posterior, Lateral, and Medial respectively.

branch system is at first discrete, then discrete in combination with other fibres, and finally a predominant one only until fibre-diffusion reaches a stage where it cannot be claimed that there is any localization; at this stage the constituent fibres of the bundles are arranged in varying combinations and proportions, though each bundle does not necessarily contain fibres from all branches.

For these reasons the longer the course of the fibres of a branch within a nerve-trunk, the greater the diffusion and the intermingling of its fibres at proximal levels. When, however, the bundles of a branch with very high origin commence to anastomose, they do so with bundles which have acquired fibres from most, if not all, of the distal branches. As a result the fibres of such proximal branches are rapidly mixed with those from several sources, but, since their intraneural course is too short to permit extensive scattering, they remain relatively discretely localized.

For the purpose of the present discussion the significant features in connexion with this funicular redistribution of fibres are:—

bundle groups, so that transverse sections taken a few centimetres apart will show it sharply localized but occupying different quadrants of the nerve. In this connexion it is also noteworthy that a change in the cross-sectional outline of the nerve, such as is produced when it moves from one position to another or is moulded into intimate relationship with a neighbouring structure, may also result in a change in the disposition of the bundle groups relative to one another and to the quadrants originally occupied by them.

Some of these intraneural shifts cannot be corrected by re-orientation of the nerve-ends because, though such a manœuvre might restore correct funicular apposition as regards the migrating bundle group, the remaining bundles, which still occupy the same position in the nerve, would then be thrown out of alinement.

3. The epineurium is not usually arranged in equal amount between the funiculi, but shows condensations which divide them into groups. At certain levels the identification and isolation of bundle groups representing particular branch systems

is facilitated because of these demarcating condensations of the epineurium.

A study of the foregoing anatomical features will explain why, in all but cases of clean severance without loss of tissue, it is impossible, during repair, Central adjustments may compensate to some extent for the distortion of patterns of innervation produced in this way, but the evidence indicates that the range within which such central adjustments are possible is limited (Sperry, 1945).

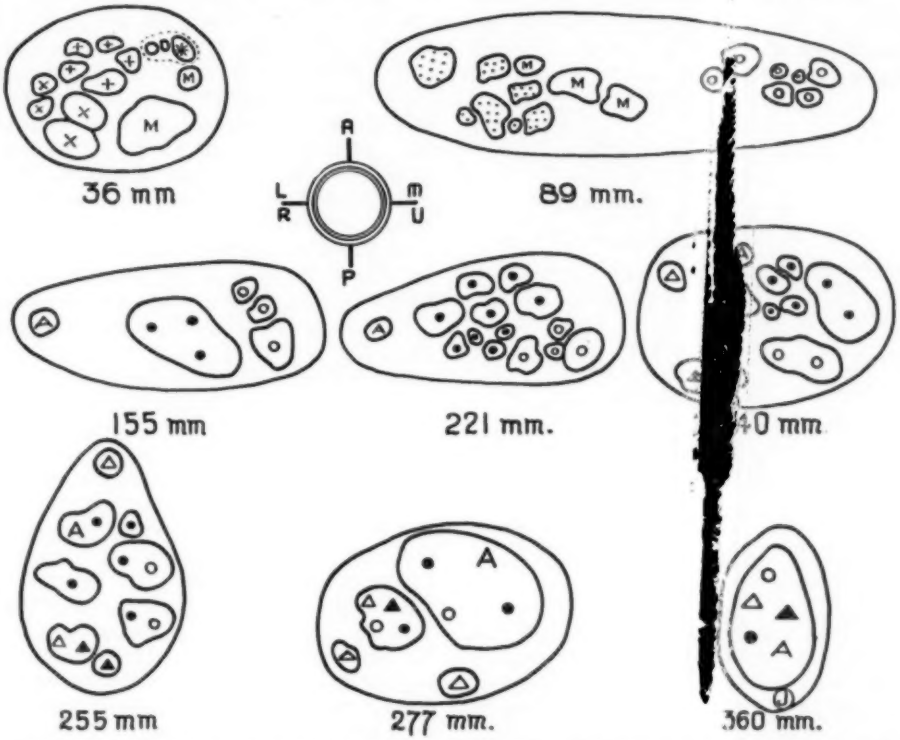

FIG. 682.—Diagrams of representative sections from a serially sectioned specimen of the ulnar nerve to illustrate: (*a*) the behaviour of fibre systems as they are traced centrally; and (*b*) the regrouping and funicular redistribution of the nerve-fibres which are effected by funicular plexus formations. The measurements give the level of the section, in millimetres, above the tip of the radial styloid process. +, Cutaneous fibres from the ulnar side of the little finger; ×, Cutaneous fibres from the fourth interspace; *, Cutaneous fibres from the hypothenar eminence; M, Deep terminal division fibres; ···, Combined superficial division fibres; ○, Dorsal cutaneous fibres; ●, Combined superficial and deep terminal division fibres; A, Fibres to the ulnar artery; △, Flexor carpi ulnaris; ▲, Flexor digitorum profundus; J, Fibres to the elbow-joint. A, P, L, M, R, and U, Anterior, Posterior, Lateral, Medial, Radial, and Ulnar respectively.

to obtain end-to-end apposition of funiculi. Several factors influence the extent of the funicular overlap, but conditions are always such that many regenerating axons escape outside the nerve and into the interfunicular tissue (Sunderland, 1952). The formation of a bulb post-operatively at the site of repair is some indication of the degree to which this wasteful regeneration occurs. This loss constitutes a serious threat to recovery.

Severance of the funiculi means also that regenerating axons are no longer confined to the endoneurial tubes and funiculi which originally contained them. During regeneration several factors combine to prevent some axons entering their old tubes and to facilitate their entry into others. The establishment of new funicular relations during repair, consequent on dissimilarities in the funicular patterns of the nerve-ends, operates in this way. This complicates regeneration in two ways. Firstly, by adding to the loss of axons which is the fate of those entering functionally unrelated tubes (e.g., motor axons into sensory tubes). Secondly, by creating a pattern of innervation which differs from the original, which is also further modified by the loss of axons outside the bundles and into functionally unrelated tubes.

MEASURES TO REDUCE THE LOSS AND ERRONEOUS CROSS-SHUNTING OF REGENERATING AXONS

An examination of the influence exerted by the foregoing anatomical features on the process of regeneration suggests two measures which may be employed to reduce the wasteful regeneration of axons and the disorganization of patterns of innervation which result from the erroneous cross-shunting of axons. These are funicular suture and funicular exclusion.

FUNICULAR SUTURE

Despite differences in the funicular patterns of the nerve-ends, the entry of axons into corresponding or functionally related endoneurial tubes would be facilitated if a bundle system representing a branch or major division of the nerve could be isolated at the nerve-ends and sutured separately. Such a procedure would be particularly useful where the fibres of the isolated bundle group differ functionally from those in the remainder of the nerve. Examples in point are the superficial radial and posterior interosseous divisions of the radial nerve, and the dorsal

cutaneous fibres and remainder of the ulnar nerve-trunk in the mid-third of the forearm.

Funicular suture would also be of great value where a change in shape of the nerve or the migration of a bundle group from one sector of the nerve to another (*Fig.* 683) results in the group occupying different quadrants in the proximal and distal stumps. Under these conditions attempts to appose the ends of the migrating bundle group by re-orientating the

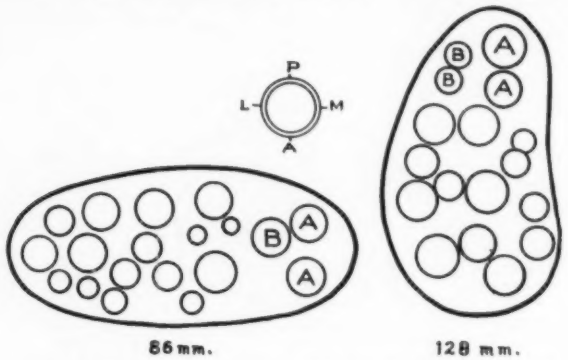

FIG. 683.—Two sections from a specimen of the lateral popliteal nerve 86 mm. and 128 mm. above the level of the knee-joint to illustrate the position of the bundles devoted to: A, Combined fibres from the sural communicating and the lateral cutaneous branch of the calf; and B, fibres from the sural communicating only. A, P, L, and M, Anterior, Posterior, Lateral, and Medial respectively.

nerve-ends would only disturb the alinement of the remaining bundles. Isolation and separate suture of the offending bundle group would, however, substantially reduce the amount of cross-shunting of axons which would result if 'whole' suture were performed.

Funicular suture was advocated by Langley and Hashimoto in 1917 as the result of studies on the internal anatomy of the sciatic nerve. They confined their remarks to this nerve, but emphasized the advantages to be gained by employing the method. Their recommendation appears to have made no impression on established practice. A detailed analysis of the internal anatomy of large peripheral nerves and of the factors influencing the quality of recovery after nerve suture indicates, however, that funicular suture does offer a chance of improving the results in some cases by eliminating what are probably the most serious factors retarding recovery. Other attempts directed to improving the results are unlikely to give full benefit while these adverse factors continue to operate.

Langley and Hashimoto mentioned three disadvantages associated with the procedure: (1) The increased time taken for the operation; (2) The possibility of increasing the connective-tissue reaction at the suture site; and (3) The division of blood-vessels might interfere with the vascularity of the isolated funiculi. The use of suture materials exciting a minimal reaction and the employment of a suture technique which does not excite or aggravate the formation of tissue prejudicial to recovery should not significantly complicate repair. Furthermore, because of the longitudinal arterial anastomoses present within and external to the bundles, the extent of the funicular mobilization required to effect separate union should not embarrass their blood-supply. Finally, the improvement in recovery which, according to theoretical considerations, should follow funicular suture, would more than compensate for the additional time involved in performing it and fully justifies an extended trial for the method.

FUNICULAR EXCLUSION

An alternative procedure to funicular suture is the exclusion of a bundle group from the suture line when the contained nerve-fibres are relatively unimportant and would, during recovery, complicate the regeneration of more important axons. For example, the principal objective of repair of the radial nerve is to restore motor function. It is known, from a study of patients with irreparable injuries of this nerve, that the sensory deficit resulting from the loss of the superficial radial cutaneous fibres is of little, if any, handicap to the patient. These cutaneous fibres, however, occupy 25 to 33 per cent of the funicular cross-sectional area of the radial nerve-trunk at the elbow (Sunderland and Bedbrook, 1950) where they are collected into a bundle group which occupies the anterior portion of the nerve (Sunderland, 1945). After suture of the radial nerve at this level regenerating sensory processes could occupy large numbers of endoneurial tubes leading to motor endings. At the same time regenerating motor axons could, as they cross the suture line, be directed into superficial radial endoneurial tubes which would lead them to the skin. This erroneous cross-shunting, which severely limits the effectiveness of motor re-innervation and recovery, is particularly likely to occur when atrophy of the distal stump and the dissimilarity of the funicular pattern of the two nerve-ends bring funiculi into apposition which are functionally unrelated.

Under these conditions it would be advisable to exclude the superficial radial bundles from the suture line. The bundle group concerned should be separated from the remaining funiculi for some distance proximally and distally, excised, and the severed ends treated in order to prevent regenerating superficial radial fibres from re-innervating the distal stump and cutaneous sensory endoneurial tubes from receiving regenerating motor axons. In other words, suture should be confined to the posterior interosseous portion of the radial nerve-trunk, and this is permitted by the funicular arrangement of the fibres at the level of the elbow-joint.

Funicular exclusion is particularly useful when the injury occurs at the site of branching and destroys a segment of the branch and the nerve-trunk. Under these conditions the fibres of the destroyed branch are represented by a bundle group in the proximal but not in the distal stump, so that when they regenerate they are free to compete for endoneurial tubes in the distal stump which originally never contained them. Recovery would be seriously affected if the axons concerned were functionally unrelated to the tubes they entered. This point will be illustrated by reference to an injury which destroys a section of the ulnar nerve at the site of branching of the dorsal cutaneous branch (*Fig.* 684). In the proximal stump the funiculi are collected into three main groups which represent, from medial to lateral, the dorsal cutaneous fibres, the deep terminal division (predominantly muscular), and the

superficial terminal division (predominantly cutaneous). Only the two terminal divisions are represented in the distal stump. Suture under these conditions approximates the dorsal cutaneous group in the proximal stump to the deep terminal division group in the distal stump. In the ensuing competition for endoneurial tubes the chances of regenerating sensory processes entering motor tubes are greatly increased and many motor axons may be prevented from restoring functionally useful pathways. This complication could be prevented by excluding the cutaneous bundle group from the suture line. On the other hand, if the bundle group in the proximal stump, which is not represented distally, contains axons which are functionally related to the endoneurial tubes in the distal stump, they should of course be used to reinforce the re-innervation of the periphery. Under such circumstances there would be no justification for excluding them.

CRITERIA TO BE SATISFIED WHEN PLANNING FUNICULAR SUTURE AND EXCLUSION

1. The bundle or bundle group should be large enough to make separate union a practicable proposition. Some are so small that efforts to unite them by techniques at present in use would be impracticable.

2. The bundle system should be sharply localized and superficially situated so that it is readily accessible and its isolation does not disturb neighbouring funiculi.

3. The bundle system should be well defined and occupy a constant position in the nerve. These features are necessary to enable it to be accurately and consistently identified at the cut ends of the nerve.

4. The bundle system should run a sufficiently long course in the nerve as an independent and sharply localized unit to permit its mobilization for the distance required to effect separate suture without damaging adjacent funiculi. In this connexion great caution must be exercised. Some of the significant anastomoses between the members of different bundle groups are very fine. Unless separation is performed gently, under some magnification and with a knowledge of the behaviour of bundles as they run in nerves, the funicular architecture of the nerve may be damaged.

It remains now to identify the regions where these criteria are satisfied and where the method of funicular suture or exclusion stands a reasonable chance of success.

THE INVESTIGATION

A detailed study of the intraneural anatomy of peripheral nerves (Sunderland, 1945; Sunderland and Ray, 1948) has suggested regions where funicular suture or funicular exclusion might be practicable. These zones have been re-investigated in more than fifty specimens of each of the major peripheral nerves with the object of determining how consistently and accurately bundle systems can be recognized and isolated.

RADIAL NERVE

Spiral Groove.—Towards the lower end of the spiral groove the posterior cutaneous nerve of the forearm can be clearly seen separating from the parent trunk. Elsewhere the bundle group representing this branch is placed, and can be easily identified and isolated as a group of from one to five bundles, along the superolateral margin of the nerve (*Fig.* 685).

In this position the posterior cutaneous of the forearm funiculi occupy 11 to 20 per cent of the

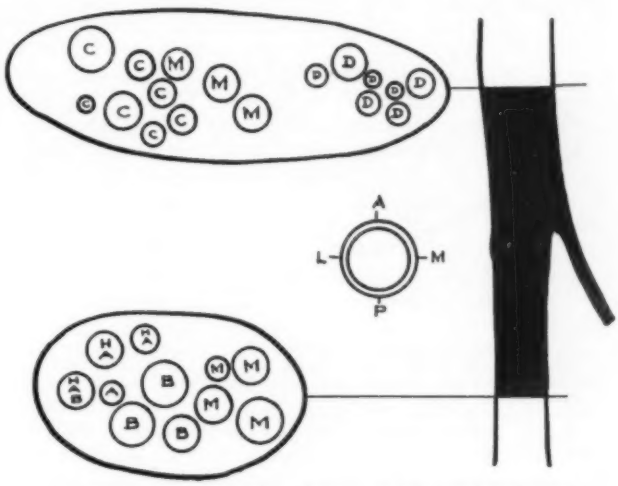

FIG. 684.—Two sections from a serially sectioned specimen of an ulnar nerve. The sections are 25 mm. apart and the dorsal cutaneous of the hand leaves the nerve from the intervening segment. If this segment of the nerve (blackened) were destroyed the proximal and distal stumps would present the funicular patterns illustrated. The funiculi for the dorsal cutaneous fibres would be present in the proximal stump but not in the distal and when the nerve was repaired these cutaneous bundles would be adjacent to those in the distal stump wich are destined for the deep terminal (muscular) branch. M, Deep (muscular) division: H, Cutaneous fibres from the hypothenar eminence; A, Cutaneous fibres from the ulnar side of the little finger; B, Cutaneous fibres from the fourth interspace; C, Combined superficial (cutaneous) division fibres; D, Dorsal cutaneous fibres. A, P, L, and M, Anterior, Posterior, Lateral, and Medial respectively.

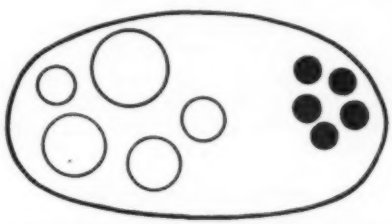

FIG. 685.—A transverse section from a radial nerve in the spiral groove to illustrate the bundle group (●) devoted to the fibres of the posterior cutaneous branch of the forearm.

total funicular cross-sectional area of the nerve. In order to prevent these fibres competing for motor endoneurial tubes in the distal stump, which is likely to occur if the 'whole' nerve is sutured, they should be excluded from the suture line or the bundle group concerned should be sutured separately and in a manner to ensure that regenerating axons from it do not reach the remainder of the trunk.

Lateral Humeral Epicondyle.—The site of division of the radial trunk into its superficial radial and posterior interosseous divisions varies, but in the majority of specimens examined it occurred at from 1 to 4 cm. below the lateral humeral epicondyle. In this region the superficial radial fibres are always

contained in a bundle group (1 to 4 in number) which is localized on the anterior surface of the nerve (*see Fig.* 681). Approximately 5 cm. above the epicondyle, however, this bundle group commences to engage in plexus formations with neighbouring funiculi. At the elbow the funiculi composed of cutaneous fibres represent 25 to 33 per cent of the funicular cross-sectional area of the entire nerve. For this reason it is advisable either to suture the group separately or to exclude it permanently from

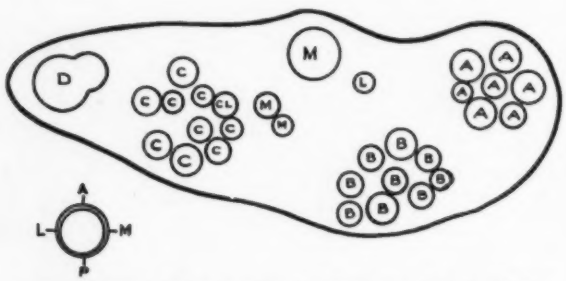

FIG. 686.—A transverse section from a specimen of the median nerve at the wrist. A, B, and C, Cutaneous fibres from the third, second, and first interspace respectively; D, Cutaneous fibres from the radial side of the thumb; L, Lumbrical fibres; M, Thenar muscular fibres. A, P, L, and M, Anterior, Posterior, Lateral, and Medial respectively.

the suture line. In some patients this introduces the risk of eliminating the fibres innervating the extensor carpi radialis brevis. Occasionally the fibres for this muscle occupy a small bundle which accompanies the superficial radial division for a short distance into the forearm before leaving it as the branch to the extensor carpi radialis brevis. This bundle can often be identified as a separate entity between the superficial radial group and the remaining bundles comprising the nerve.

At levels above the origin of branches to the brachioradialis and radial extensors of the wrist care should also be taken to avoid the funiculi-bearing fibres for those branches. This is not difficult, because these bundles are localized anterolaterally and engage in plexus formations amongst themselves before finally involving bundles of the superficial radial group (for details, *see* Sunderland, 1945, 1946).

MEDIAN NERVE

The median nerve rarely offers opportunities for funicular suture. Following injuries in the axilla, the medial and lateral roots of the nerve may be repaired separately. Occasionally the two roots of the nerve proceed distally for some distance as separate entities, which favours separate repair in the upper part of the arm. Usually, however, the adjacent funiculi of the two roots commence to intermingle and anastomose within a centimetre of the site of macroscopic union of the roots. Though some of the funicular cross-unions developed in this way are very fine, they nevertheless impose conditions which make it unwise to attempt any separation of the median nerve into sections representing roots.

At the wrist the median nerve is usually composed of a large number of small bundles (*Fig.* 686). Though the terminal branches are precisely localized in terms of the funiculi, the arrangement and size of the bundles are such that funicular suture would be impracticable. Branch suture may become possible further distally where the branches are beginning to separate away from the parent trunk. This, however, would be an example of branch suture rather than of funicular group suture.

ULNAR NERVE

There are two regions where funicular suture or exclusion could be employed with advantage—namely, at the wrist and in the mid-third of the forearm.

Wrist.—At the wrist the fibres destined for the deep division of the nerve are localized in a group of funiculi occupying the medial and posteromedial portion of the nerve (*see Fig.* 682). In this situation these fibres are usually collected into one large bundle with a variable number of small satellites. This group can be easily separated from the remaining bundles which are small and are devoted to the fibres continuing as the superficial division of the nerve. The individual digital branches are discretely localized to their own funiculi in the latter group but, as in the case of the median nerve at this level, the bundles are usually too small and the line of demarcation between the subgroups too indistinct to permit funicular suture. The superficial (predominantly cutaneous) and deep (predominantly muscular) divisions can, however, be identified and separated without difficulty at, and for a distance of about 1 cm. above, the level of the wrist-joint. Here the deep and superficial division fibres occupy approximately 45 and 55 per cent respectively of the funicular cross-sectional area of the ulnar trunk.

The funicular localization obtaining at this level favours the entry of axons into functionally related tubes following repair. On the other hand, the percentage distribution of the cutaneous and muscular fibres is one which would facilitate the erroneous cross-shunting of axons and therefore justifies separate suture of the two different bundle systems.

Mid-third of Forearm.—In the mid-third of the forearm the bundle group representing the dorsal cutaneous of the hand occupies the medial and posteromedial portion of the nerve. The group can be identified and isolated from the point where the branch joins the trunk, at the junction of the mid- and distal third of the forearm, as far centrally as the junction of the proximal and mid-third of the forearm. At the latter level the dorsal cutaneous bundles commence to anastomose with neighbouring bundles bearing other fibres. The length for which the group pursues an independent course varies from 15 to 20 cm. The number of bundles in the group varies from one to eight.

In the mid-third of the forearm fibres of the dorsal cutaneous branch occupy approximately 20 per cent of the funicular cross-sectional area of the nerve. Furthermore, the bundle group containing these fibres is situated immediately medial to that composed of the muscular fibres destined for the deep division. Therefore when suturing the nerve in this region steps should be taken, either by separate suture or exclusion, to prevent the cutaneous fibres from regenerating into neighbouring bundles which are occupied by tubes which before the injury contained motor axons.

SCIATIC NERVE AND ITS POPLITEAL DIVISIONS

Thigh.—The two popliteal divisions of the sciatic nerve may appear in the buttock and proceed distally as separate trunks. However, even when they are combined to form a single trunk, which is the usual arrangement, there are no funicular intercommunications joining them, and the two can be identified and separated at the cut ends of the severed nerve. There are two additional points of importance in connexion with the internal anatomy of the sciatic nerve :—

1. The funiculi occupy only 18 to 30 per cent of the cross-sectional area of the sciatic nerve in the buttock, the supporting epineurial tissue representing the bulk of the nerve (Sunderland and Bradley, 1949).

This feature, together with the small size of the bundles and the manner in which they are openly arranged, combines to increase the chances of funicular overlap. Separate suture of each division of the sciatic nerve would go some way towards eliminating the loss of axons into the interfunicular tissue and the wasteful cross-shunting of others into functionally unrelated tubes.

2. Owing to the large amount of epineurial tissue, the line of separation between the two divisions is not always as obvious as might first appear. In the thigh this line runs anteroposteriorly through the nerve, but in the buttock the line is obliquely placed so that portion of the lateral division overlaps the medial division posteriorly. This point should be kept in mind when separating the divisions preparatory to undertaking independent repair.

Lateral Popliteal Nerve.—The bundle group containing the cutaneous fibres from the sural communicating and lateral cutaneous branch of the calf runs an independent course in the main trunk of the nerve for a distance of approximately 15 cm. above the knee-joint. Over this length these fibres occupy 13 to 30 per cent of the funicular cross-sectional area of the nerve-trunk (Sunderland and Bedbrook, 1950). After joining the nerve the bundle group occupies a medial position for about 5 cm. and then turns on to, and ascends along, the posterior surface. It can usually be identified and isolated in the distal fourth of the thigh and its exclusion from the suture line would prevent this sensory component complicating the regeneration of motor axons. An alternative procedure would be to repair it separately. The migration of the bundle group from the medial to the posterior surface of the nerve should be borne in mind when undertaking these procedures.

Medial Popliteal.—The tibial nerve can be separated into medial and lateral plantar bundle groups in the distal third of the leg. The medial plantar group occupies approximately the medial half and the lateral group the lateral half of the nerve.

GENERAL

Though there are other regions where branch systems occupy separate and localized bundle groups, the latter are more variable in their disposition and are so fine and difficult to identify at the nerve face that it would be unwise to attempt funicular suture. Where there is a serious element of uncertainty which could result in errors in identification, the erroneous cross-shunting of regenerating axons might be increased rather than reduced.

GENERAL CONCLUSIONS AND SUMMARY

A detailed analysis of the internal anatomy of large peripheral nerves and of the factors influencing the quality of recovery after nerve suture indicates that funicular suture and funicular exclusion, where practicable, offer a chance of improving results by reducing the influence of what are the most serious factors limiting recovery. The factors concerned are those which favour the wasteful regeneration of axons into the epineurial tissue and functionally unrelated endoneurial tubes, and the erroneous cross-shunting of axons all of which combine to reduce and distort the original pattern of innervation. Other attempts directed at improving the results of nerve suture are unlikely to give full benefit until consideration is given to these points.

The advantages to be gained by employing funicular suture and funicular exclusion have been outlined, while attention has been directed to the criteria which must be satisfied before these procedures should be attempted.

Regions have been indicated where such a technique may be employed with safety. Though few in number, they are worthy of consideration. The results of nerve repair are frequently disappointing and the residual disability resulting from nerve division, even after the most skilled attempts at repair, may so seriously impair the function of the entire limb that any technique which offers a chance of improved recovery merits attention.

The technique is obviously complicated, has a limited application, and requires a detailed knowledge of the internal anatomy of nerve-trunks together with repair under low magnification. These, however, should not be excessive demands to the enterprising surgeon. It is common practice when a nerve-trunk and an adjacent branch have been severed to suture each separately. There should be no difficulty in extending the procedure further proximally to a level where the bundle group representing the branch can still be separated from the remainder of the nerve-trunk. A review of surgical achievements over the past twenty years demonstrates the significant advances which have emerged solely as the result of refinement of techniques. Unless there is a corresponding effort on the part of those responsible for the repair of nerves, little improvement can be expected.

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THE DIAGNOSIS OF THE DEPTH OF BURNING

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DURING the last few years primary excision of dead tissue and immediate skin-grafting have been recognized as the treatment of choice for burns destroying the whole thickness of the skin. This procedure is based on three principles: first, it is better to excise dead tissue and close the wound than to allow spontaneous separation of the slough to occur, with its attendant risks of infection, fibrosis, and loss of function; secondly, when there is destruction of the whole thickness of the skin over a sufficiently large area grafting is always required eventually, either to obtain healing or to correct contractures resulting from shortage of skin; and lastly, the best surgical results are obtained in the shortest time by this method of treatment.

The diagnosis of full-thickness skin loss, however, is often difficult immediately after burning, and in the past it has usually rested upon the intuition that comes from experience rather than upon accurate description and definition.

This study was undertaken in order to find physical signs upon which the early diagnosis of the depth of necrosis might be based.

HISTORICAL REVIEW

One of the first classifications of burns was that proposed by Fabry, which contained no reference to the depth of burning (Sonnenburg and Tschmarke, 1915). It was a classification of the *intensity* of surface burning, judged by external appearance, and recorded in three degrees, which were:—

1. Redness and blistering of the skin.
2. Withering of the skin without charring.
3. Eschar formation and charring.

This type of classification, based on surface appearance but with the occasional introduction of additional physical signs, stood with only minor alterations for nearly two hundred years.

It was not long, however, before the surface appearance became identified with the depth of burning, a mistake which is still the source of considerable confusion. This association is reflected in the classification of Richard Wiseman and recorded in his discussion on gunpowder burns (Wiseman, 1676):—

1. "Superficial, it raiseth the cuticle up in blisters."
2. "Deeper into the skin . . . it causeth an eschar."
3. "Deeper into the flesh . . . it makes a hard crust with a contraction."

Fabry's classification developed in two directions: one was towards a classification based on the depth of burning, and the other towards a classification based upon pathology. Examples of the first are the classifications of Heister (1739, trans. 1743) and Dupuytren (1832): instances of the second are those of Kentish (1817), and of Delpech (quoted by Sonnenburg and Tschmarke, 1915), who proposed two degrees only, namely, inflammation and destruction.

Dupuytren criticized the previous classifications because they were concerned chiefly with the intensity of burning and did not give enough consideration to the depth of tissue destroyed. Nevertheless he admitted that the degrees of his own classification were in most cases difficult to distinguish immediately after the accident.

The most recent classification of burns which has gradually been adopted during the past ten years has completely forsaken all reference to the outward appearances, which are only a measure of the severity of surface burning. In this classification there are two degrees:—

1. Partial-thickness skin loss, implying the presence of sufficient living epithelial elements to resurface the area; and
2. Full-thickness skin loss, implying virtually complete destruction of all epithelial elements so that natural healing can only occur by contraction of the wound and epithelial cell migration from its edge.

To differentiate these two depths of burning the following four criteria and procedures have been explored: (*a*) the presence of visible dermal circulation; (*b*) the fluorescein test for the presence of dermal circulation; (*c*) the staining reactions of the surface of the burn; (*d*) the sensitivity of the burn to pin-prick.

In the early years of the last war the presence of dermal circulation, as judged by redness blanching on pressure, was regarded as evidence of partial-thickness skin loss (National Research Council of Canada, 1942). However, as shown in this study, visible dermal circulation during the first 24 hours after injury is no index of partial skin loss, and the absence of visible circulation is no criterion of total skin destruction.

In 1943 intravenous injection of fluorescein was proposed as "a clinical test for differentiating second and third degree burns" (Dingwall, 1943). As a guide to the diagnosis of full-thickness skin loss in borderline cases this test failed for the same reason as before, since the fluorescein merely showed up the areas which possessed a circulation in the superficial dermis. During the twenty-four hours after burning, the circulation in tissue damaged by a certain intensity of heat gradually becomes arrested: this process is discussed later. Burns in which the superficial circulation ceases during this period may have partial or complete skin destruction.

A third method was introduced by Patey and Scarff (1944), who used a modified van Gieson's stain applied to the surface of burns to show up the areas of dermal necrosis. Mapping out the areas of *surface* necrosis with dyes, like noting the presence or absence of circulation, tells of nothing deeper than

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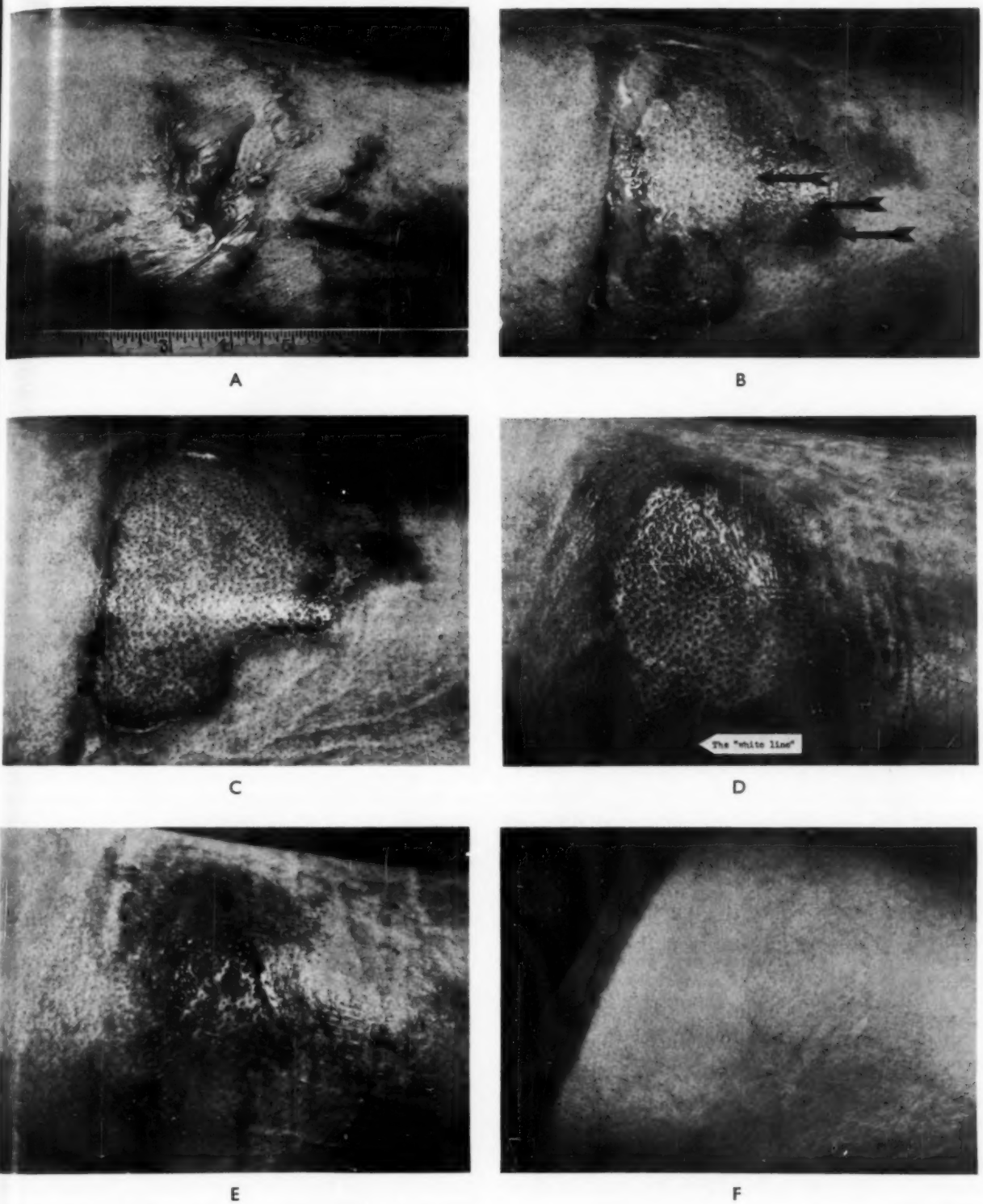

FIG. 687.– A, *The day of injury*. The central area was white and analgesic, and the surrounding area pink, blanching on pressure and hypo-algesic. B, *2nd day*. The three zones of hyperæmia, stasis, and coagulation were present and are marked with arrows in the figure. C, *3rd day*. Only two zones were evident – the zone of hyperæmia, and the rest which was white with red nodules. D, *13th day*. Epithelialization had spread centrally to the 'white line', and dense speckling has appeared except in the deepest central area. E, *22nd day*. The translucent epithelium of the speckled zone had become opaque, but the deep central area remained unhealed till the end of the fourth week. F, *1 year*. The texture of all the healed skin was normal. The area within the white line was pigmented at 3 months but paler than normal at a year.

the eye can see, whereas the critical layer in burns is the deepest plane of living epithelial elements.

The ideal method would be to map out the deep remnants of the hair follicles and sweat-ducts, but the nearest approach to this so far has been to map out the area where living skin remained beneath the burn. This has been done by using sensation, which is a property of living skin which is retained even when it is covered by superficial slough. The correlation between analgesia and the depth of burning was studied experimentally by Bull and Lennard-Jones (1949), and their findings have since been modified to form the simple clinical test of the depth of burning which is described below.

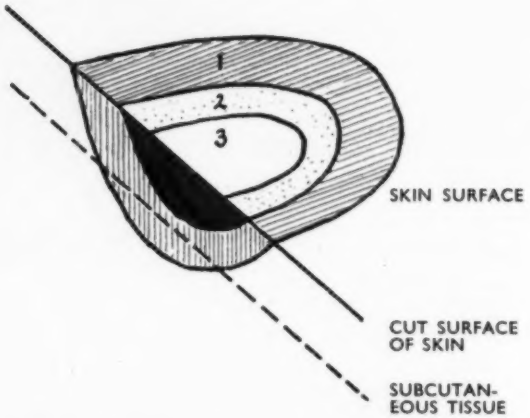

FIG. 688.—Shows the three zones of intensity: (1) The zone of hyperæmia (peripheral). (2) The zone of stasis (intermediate). (3) The zone of coagulation (central). The two inner zones of necrosis (shaded black) do not penetrate the skin.

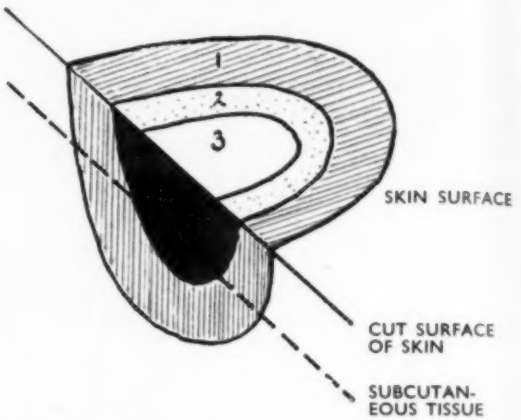

FIG. 689.—Shows the same surface appearance associated with complete skin destruction, the zones of necrosis (shaded black) penetrating the full thickness of the skin.

THE APPEARANCES OF BURNED SKIN

In many thermal injuries the diagnosis between partial- and full-thickness skin loss is simple. In this study, however, borderline examples where the diagnosis was in doubt were selected for special investigation. Both burns and scalds were studied, and apart from a few initial differences such as exudation and charring they were found to be very similar. Twenty chosen patients were studied in detail with daily dressings, and in addition the observations have been checked repeatedly in over 1200 serious in-patient burns during the last three years.

The appearances described are those seen after removal of blistered epidermis and fibrinous exudate, and during these observations the burns were dressed with penicillin cream (Colebrook, 1950) and covered with dry gauze, wool, and a crêpe bandage. With exposure or coagulative methods of treatment these appearances would not be seen, since dead, avascular dermis is converted into a hard dry crust by these methods.

Before describing the appearances of burns in detail, there are two features about them which should be noted.

Most burns and scalds are deepest in the centre and most shallow at the periphery, so that the appearance tends to be one of concentric zones. In the following description of the three-zone burn, it is to be understood that this is the most general case: not infrequently one or more of these zones may predominate to the exclusion of the others, but usually all three zones are seen in any extensive burn.

Furthermore, the appearances of a particular burn fall into two main groups. The appearances of the first week are due to the state of the superficial dermal capillaries and the blood in them: depending on their state, the appearance will be red or white, and either blanching on pressure or remaining red. During the subsequent fortnight the superficial necrotic layers of the dermis separate and the deeper layers of the skin become exposed. The appearances of the first week, which depend on the vascular state of the superficial layers of the dermis, are of little value in the diagnosis of the depth of burning; on the other hand, the appearances of the subsequent fortnight, which are those of repair, have a definite diagnostic significance. The appearances of the second and third weeks are independent of those of the first.

The periods of time mentioned are only approximate. Like others, we have found that the rate of healing varies not only with the depth but also with the site of burning (Clowes, Lund, and Levensen, 1943), as well as from one individual to another.

1. The Appearances of the First Week.—During the first day after injury the burn is characterized by three concentric zones which illustrate three degrees of intensity of burning of the dermis: they are the zones of hyperæmia, stasis, and coagulation (*Figs.* 687 B, 688).

a. The Outer Zone of Hyperæmia.—This red zone blanches on pressure and becomes cyanosed with the rest of the limb if a pneumatic cuff is applied proximal to the burn for ten minutes. This indicates that it has a circulation and that metabolism is taking place. These characteristics do not change: the zone becomes a deeper red by the fourth day, and is dry and healed by the seventh. A biopsy of this zone shows almost complete loss of the epidermis without apparent structural damage to the dermis. The subpapillary plexus and capillary loops are patent (*Fig.* 690).

b. The Intermediate Zone of Stasis.—This zone is initially red and blanches on pressure, so that one may assume that the subpapillary plexus is patent and contains oxygenated blood. On applying an exsanguinating tourniquet the zone becomes white, and on removing the tourniquet the colour returns to the burn as it does to the rest of the limb: this shows that the blood is not just squeezed from one part of the subpapillary plexus to another, but that it is in the general circulation. If a pneumatic cuff is then applied above the burn to arrest the circulation for ten minutes, the skin of the hand or foot becomes obviously cyanosed but the zone of stasis remains bright red. This suggests that oxyhæmoglobin in the subpapillary plexus in this zone is not reduced, but that metabolism here is much diminished or has ceased.

By the end of twenty-four hours the circulation through these superficial vessels, as shown by the pressure and tourniquet tests, has ceased. Petechial hæmorrhages may be present, visible to the naked eye, and on microscopical examination the superficial capillaries are dilated and packed with red cells. Complete stasis has occurred. (*Fig.* 691.)

Between the third and seventh days the red and white mottling of the zone of stasis turns white, so that only two zones are then apparent; these are the red hyperæmic outer zone and an inner white area consisting of the two zones of stasis and coagulation together. (*Fig.* 687 C). The zone of stasis at this stage is white because the superficial surface of the dermis is avascular and necrotic, and the red cells which previously coloured the zone have hæmolysed.

c. The Central Zone of Coagulation.—On microscopy this white coagulated skin is characterized by complete obliteration of the lumina of the vessels in the subpapillary plexus and the capillary loops; only an occasional solitary red cell can be seen (*Fig.* 692). Temporary blanching has frequently been observed as the first response of capillaries to heat (McMaster and Hudack, 1934; Leach, Peters, and Rossiter, 1944), and it is probable that this white skin of the central zone is produced by coagulation of the tissues during this transient period of spasm by some temperature over 70–80° C.

Comment.—It should be emphasized that the appearances of the intermediate and central zones have no significance in the diagnosis of the depth of burning. Initial white coagulation of the skin does not necessarily imply full-thickness skin loss, and this warning applies much more to the extended area of white necrosis on the surface of the burn after the zone of stasis has turned white. Those who excise the white areas of a burn at seven to ten days after burning, taking colour as their criterion of complete skin destruction, will frequently excise skin that would heal naturally in two to three weeks with no scar.

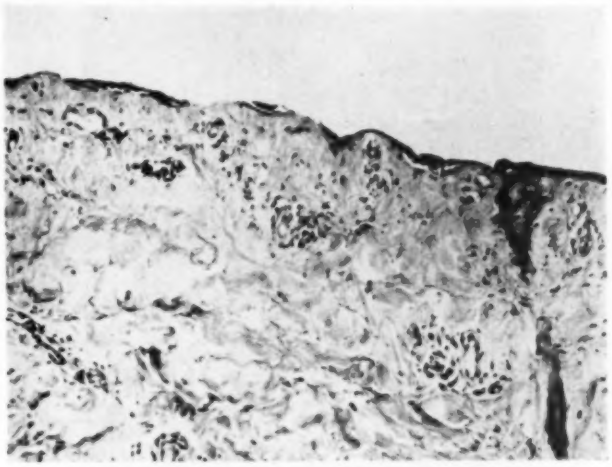

FIG. 690.—Burned skin from the zone of hyperæmia. The epidermis has been lost, but even the most superficial capillaries in the dermis are patent (3 days after injury).

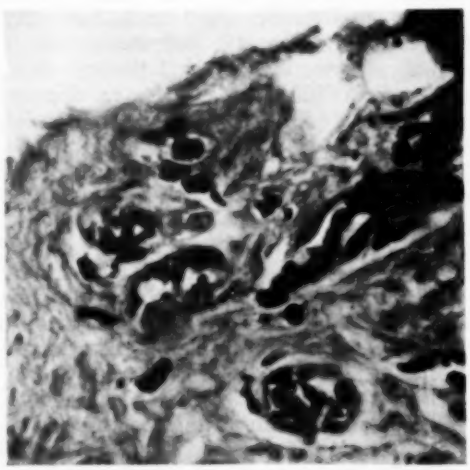

FIG. 691.—Burned skin from the zone of stasis. The capillaries are grossly dilated and packed with red cells (4 hours after burning).

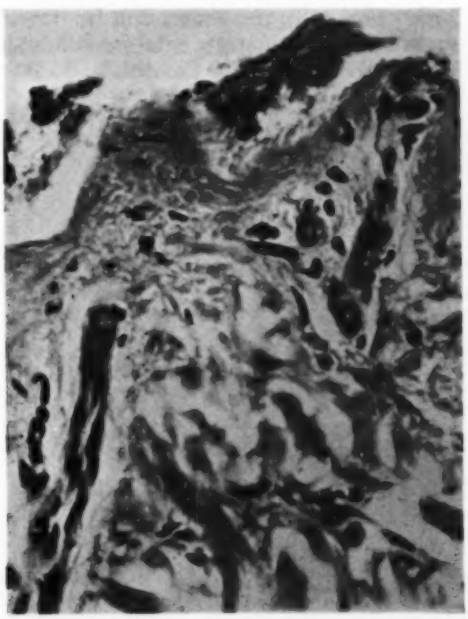

FIG. 692.—Burned skin from the zone of coagulation. The capillaries have been coagulated in a state of spasm and no lumen is visible (4 hours after burning).

Although one knows that the tissue of the two inner zones will be cast off, it is not possible by surface inspection alone to tell whether these zones include the whole thickness of the skin or not. If

FIG. 693.—Burned scalp from a child of 7 months. The hair follicles extend deeply into the subcutaneous fat.

they do not (*Fig.* 688), the lesion will be partial skin loss only, but if they penetrate into the subcutaneous tissue (*Fig.* 689), there will be full-thickness skin loss.

FIG. 695.—A section of skin parallel to the skin surface, showing a hair follicle implanted into the summit of the fat dome.

The appearances of the first week indicate the intensity of burning only, and early diagnosis of the depth of burning must be largely indirect from the history and from sensation tests as described below.

2. The Appearances of the Second and Third Weeks.—These appearances are determined by the anatomy of the skin at its junction with the subcutaneous tissue.

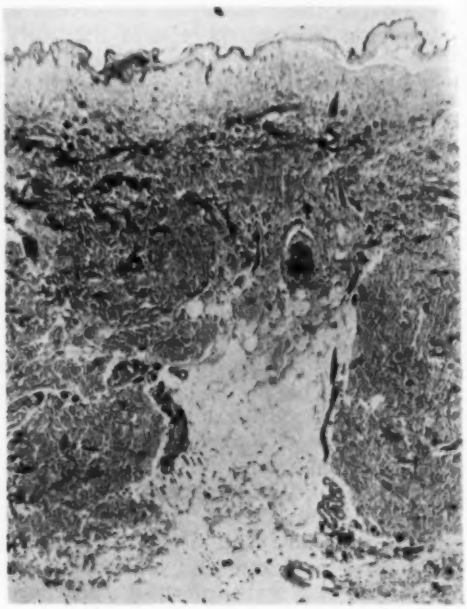

FIG. 694.—Burned skin from the back of an adult. It shows a hair follicle close to its roots in the summit of a fat dome, and more deeply placed sweat-glands.

The critical plane of the skin in burns is the deepest plane at which epithelial structures occur in sufficient numbers to permit adequate epithelialization from below. In some sites such as the scalp, face, palm, and sole, this plane is deep in the subcutaneous tissue (*Fig.* 693), but usually it is at the junction of the fat and the dermis. Here the normal architecture is as follows: domes of fat cells project up into the lower dermis, and prolongations of dermal collagen extend down between these domes (*Fig.* 694). The hair follicles are planted with their erector muscles into the summits of the fat domes, two or three in number to each dome: when two or three hairs arise over one fat dome, usually only one reaches right down into the fat. Most of the sweat-glands are situated between the fat domes and the collagen pillars at a deeper level than the hair roots, and their ducts ascend spirally through the dermis to appear between the hairs.

It follows that when sections of skin are cut in a plane parallel to the skin surface at the level of the lipodermal junction, the pattern is that of a collagen net with holes in it which are filled with fat. This is the pattern seen in the stage of repair after deep burning of the skin. Hair follicles will be present if the plane of section is at the level of the summits of the fat domes (*Fig.* 695), only sweat-ducts and glands will be present if the plane is slightly deeper (*Fig.* 696), and no epithelial elements will be present if the plane is deeper still (*Fig.* 697). The net pattern, however, will be present in all three planes, and it is not peculiar to partial- or full-thickness skin-loss burns.

Starting at about the seventh day, epithelialization begins to take place from the inner edge of the hyperæmic zone. The onset is not easy to see because the collagen net is still white when first covered with epithelium, and the red 'nodules'

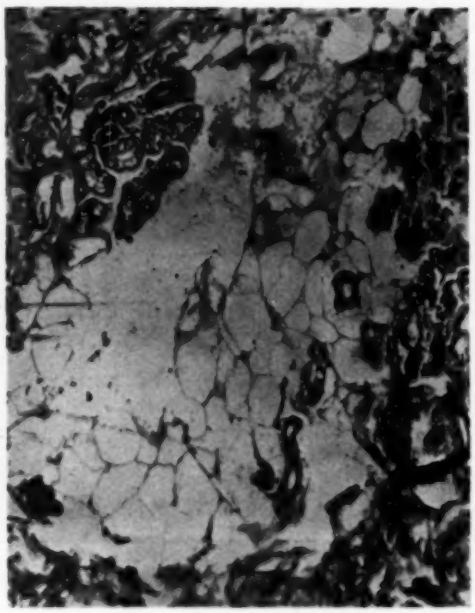

FIG. 696.—A section of skin, at a slightly deeper plane than in *Fig.* 695, through the sweat-glands and ducts.

filling the holes of the net look the same immediately after epithelialization as before it. Very careful inspection is needed after drying the surface by exposure, or under a hot lamp, to see the thin translucent film of epithelium, and sometimes it can only be seen by putting it on the stretch to throw it into folds. The epithelium *appears* to spread inwards from the edge: this is because it only becomes visible when the superficial dead dermis has been shed (*Fig.* 698), and in most burns this necrotic layer is thickest at the centre. Also fewer foci for epithelial regeneration occur in the deeper parts of the burn.

At about the fourteenth day the inward spread of epithelium temporarily ceases with the formation of a 'white line' (*Fig.* 687 D): this can be seen in microscopical sections to coincide with the inner edge of the epithelium. The white line marks the boundary between what has healed from hair follicles and what will heal from sweat-ducts.

During the second week, as the white necrotic collagen slough central to the white line becomes thinner, the pattern of the collagen net and nodules emerges even more clearly and 'speckling' appears as small red dots on the white cords of the net (*Figs.* 687 D, 699 B). Microscopical preparations show that these dots are formed by hyperæmic capillaries at the sites of the sweat-ducts, and they are of importance because they indicate the presence of viable sweat-ducts from which healing can take place. A stage of speckling is the rule in partial skin-loss burns of the palm or sole, but it has not been seen on the face or scalp where epithelialization from hair follicles is rapid.

Following the appearance of speckling the sweat-duct epithelium becomes visible as a translucent film at about the fourteenth day if the surface is allowed to dry (*Fig.* 699 C), and it takes about ten days to thicken to the opacity of normal skin.

FIG. 697.—A section of skin, at a slightly deeper plane than in *Fig.* 696, and under lower magnification. The collagen net is present deep to all epithelial elements.

The next deepest plane which can be recognized by its surface appearance is that which passes deep

FIG. 698.—A section of a partial skin-loss burn excised on the sixteenth day. Epithelium from a sweat-duct is spreading out beneath some collagen slough.

to all epithelial elements, but not deep to the collagen net. This is characterized by the same net and nodules as the previous one, but without any speckling, and this indicates full-thickness skin loss (*Fig.* 687 D).

Finally, there is the burn, slightly deeper still, in which the net is destroyed altogether, and the white slough of dead dermis is replaced within sixteen to twenty days by homogeneous granulation tissue.

Comment.—These appearances of the second and third weeks are the appearances of repair, and considered in relation to the age of the lesion they are a help in the early diagnosis of full-thickness skin loss. The appearance of abundant speckling in the second week means that the lesion will be covered with skin of good texture in the next fortnight. A central area of scattered or absent speckling within a surrounding zone of abundant speckling should be regarded as virtually complete skin destruction, and grafting should be undertaken without delay. As a rule, areas unepithelialized at 16–20 days after injury should be grafted at once unless it seems certain that they will be healed in another week.

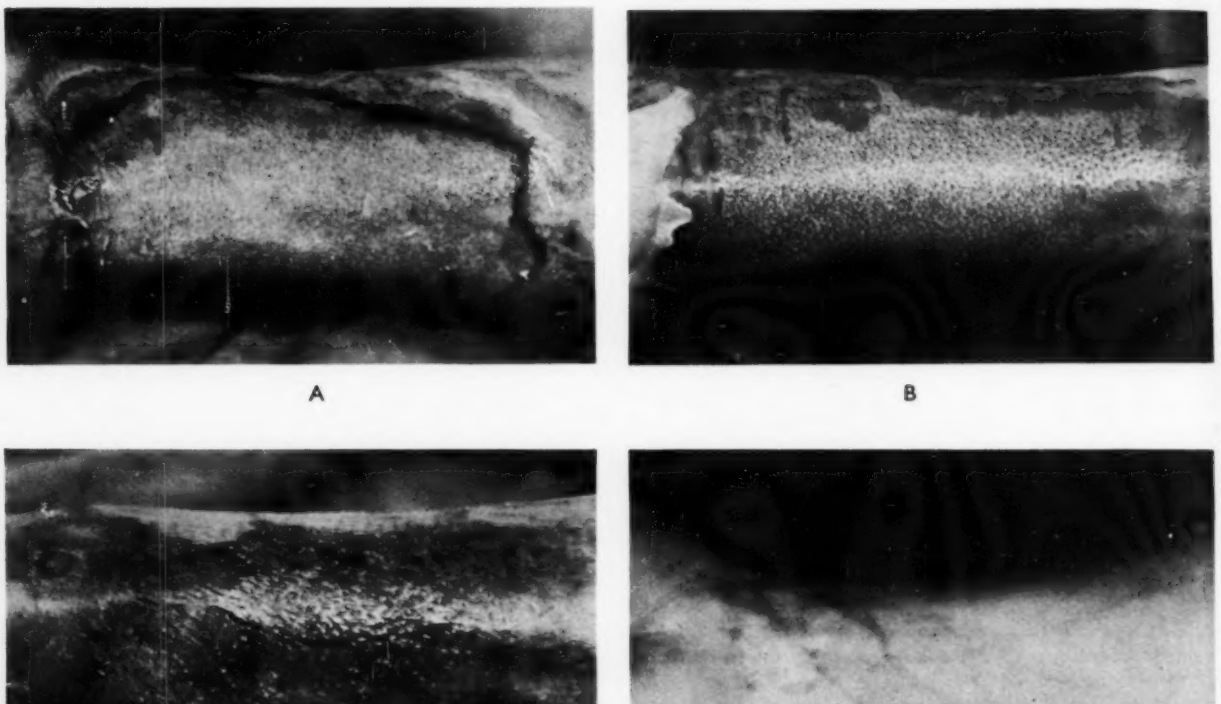

FIG. 699.—A, *The day of injury.* The area of analgesia was marked out on the scald, which was mostly white. B, *9th day.* Speckling was very dense and therefore natural healing was expected by about three weeks. C, *20th day.* Epithelialization was complete but several more days were required before it had thickened and was strong. D, *55th day.* The texture of the skin was completely normal but temporary pigmentation was present for some months.

THE SENSITIVITY OF BURNED SKIN

The alteration in the pain sensitivity of burned skin has been recognized for many years. It was described by Dupuytren (1832), and more recently by Colebrook (Colebrook, Gibson, and Todd, 1945) and by Cope (Cope, Langohr, Moore, and Webster, 1947). The most recent account has been by Bull and Lennard-Jones (1949), who made a detailed investigation of burns produced experimentally upon themselves, and out of their work the following clinical test has developed.

The Method of Testing for Analgesia.—The test is first explained to the patient if he is old enough to understand and he is reassured that he will not experience any serious pain. Then the burn is tested for sensitivity to pin-prick with a sterile hypodermic needle held in a sterile hæmostat. At first the lesion is touched lightly where the burning is of greatest intensity, in case pain sensation is present, and then the needle is pressed firmly upon the skin before the presence of analgesia is recorded. One prick is valueless: about ten to the square inch are required, not only because the pain spots are localized but because areas of full-thickness skin loss may be patchy in the burn. The age of the patient and his nervousness must be taken into account as with all subjective tests, but both these sources of error tend towards conservative treatment.

In this study the relationship of analgesia to the depth of necrosis was investigated by testing the sensitivity of burns to pin-prick on admission (*Figs.* 687 A, 699 A), and noting subsequently whether they

proved to be partial- or full-thickness skin loss. As a result the following associations soon became apparent :—

1. Any appreciation of pain, as opposed to touch, on pricking with a pin signified partial skin destruction only.

2. Full-thickness skin-loss burns were always analgesic.

3. Analgesia was not only present when the skin was completely destroyed, but was sometimes found in deep partial skin-loss burns also.

4. Analgesia associated with deep partial skin-loss burns was more common on the face, scalp, palms, and soles than on areas of non-specialized skin.

5. Analgesia was common in superficial burns caused by alkalis and acids, especially carbolic acid.

It may be seen, then, that deep partial skin-loss burns which heal from sweat-ducts may be either hypo-algesic or analgesic. This suggests that the deepest level of pain sensitivity is slightly superficial to the lower ends of the sweat-ducts in non-specialized skin.

THE CLINICAL DIAGNOSIS

Some burns are obviously coagulated down to the subcutaneous tissue and present no problem in diagnosis. In burns of doubtful depth, however, analgesia is the most reliable early sign that the burn is deep. Nevertheless, analgesia does not imply that the burn is necessarily full-thickness skin loss, so that in making the diagnosis of the depth of burning it must always be considered together with the history of injury and the site of the burn.

History.—Burns with molten metal and red-hot metal are almost always full-thickness skin loss ; so also are electric contact burns which are frequently associated with even deeper necrosis. White, analgesic burns on the palms due to the hands being clenched in faradic spasm on the bar of an electric fire are usually, though not invariably, whole skin loss. Full-thickness flame burns in epileptics are often easy to diagnose, having the appearance of translucent parchment through which the thrombosed subcutaneous veins can be seen. High temperature liquids such as hot fat, tar, resin, and sugar solutions usually cause mixed lesions like scalds produced by hot water. Acid burns frequently prove to be partial-thickness skin loss, even though they may be white and analgesic immediately after injury.

Special Skin Areas.—Apart from the obvious full-thickness skin-loss burns seen in epileptics, analgesic burns of the face and scalp should not be excised primarily : the hair follicles penetrate beyond the dermis so that very deep burns often recover with minimal scarring if left for two or three weeks. Similarly, the palm and sole should be spared in any case of doubt, as regeneration from deeply placed sweat-ducts in these sites often occurs. There are some areas such as the back of the hand where deep partial skin-loss burning heals with such poor skin texture that it is better to excise and graft it at once than treat it conservatively. For this reason the majority of analgesic burns on the back of the hand, not caused by chemicals, should be considered for immediate excision and grafting.

If, after these considerations, there is still doubt about the depth of an analgesic burn and the best treatment for it, the management should be planned with special reference to the expected healing time and the texture of the skin which will result. Primary excision may save from two to four weeks in healing time ; on the other hand, if the burn is partial-thickness skin loss, excision and grafting will probably produce skin of poorer texture both functionally and cosmetically. It is never justifiable to excise a new burn in a child if the presence of full-thickness skin loss is in doubt, and only rarely, for economic or social reasons, in an adult.

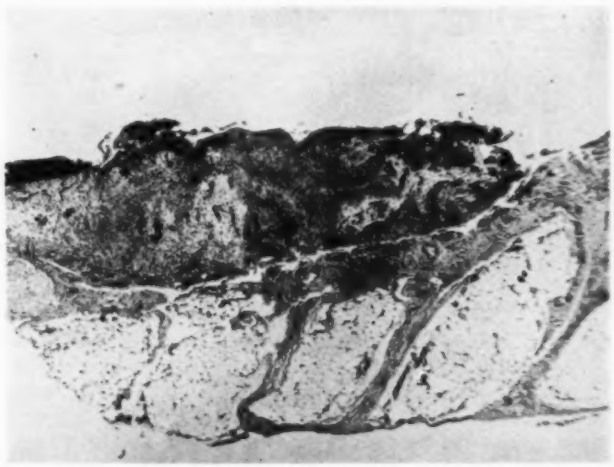

FIG. 700.—A section of a full-thickness skin-loss burn on the twenty-second day. A flap of granulation tissue was scraped off, replaced, and then excised with its base. The plane of separation is just superficial to the remains of the fat domes.

Sometimes a definite diagnosis of full-thickness skin loss cannot be made on the day of injury, and then ' delayed grafting ' (by which is meant grafting after the first 24 hours) becomes necessary. About the optimum time for this there is wide variation of opinion.

Some surgeons choose a time between the fifth and tenth days for excising and grafting, using the superficial white necrotic slough as a guide to the amount of full-thickness skin loss. But we have seen that this is no criterion of complete skin destruction, and in our experience burns which can justifiably be excised during this period (excluding the burns of shocked patients) can be diagnosed more reliably and grafted more successfully on the day of injury. No physical sign of full-thickness skin loss appears during the first week which was not present on the day of burning, and the base of the burn becomes more vascular after the first day, which makes hæmostasis and successful grafting more difficult.

The principle of securing skin cover for an open wound at the earliest moment is generally accepted. Sometimes the pattern of speckling enables the surgeon to excise and graft an area of full-thickness skin loss in the second week, and it is almost always possible to diagnose the limits of skin destruction by the sixteenth to eighteenth day. At this stage further delay to prepare the granulation tissue for

grafting serves no purpose, and subjects an extensively burned patient to a further one or two weeks of wasting and risk of infection. If the granulation tissue has too many tags of unseparated slough to take a graft directly, it can be stripped off easily by blunt dissection at the level of the summits of the fat domes, leaving an ideal surface for grafting (*Fig.* 700).

The optimum time for grafting, therefore, is as soon as the limits of full-thickness skin loss can be diagnosed, and not later than three weeks. The more extensive the burn, the more important it is to keep to this timetable.

SUMMARY

1. The importance of the early diagnosis of the depth of necrosis in the treatment of burns is emphasized.

2. A brief historical survey shows how a classification of burns based upon the *intensity* of burning has developed into one based upon the *depth* of tissue destruction.

3. The appearances of healing burns and scalds have been studied to find out which of the local physical signs are of value in diagnosing the depth of burning.

4. These appearances were found to fall into two main groups, namely :—

a. Those of the first week, which are due to the vascular state of the superficial dermal capillaries ; and

b. Those of the subsequent fortnight, which are due to the processes of repair at different depths of burning.

The appearances of the first week are of little value, while those of the subsequent fortnight can be useful as diagnostic signs of the depth of burning.

5. The significance of analgesia in recent burns has been studied and evaluated.

6. The clinical application of these physical signs to the diagnosis of the depth of burning has been described.

I wish to take this opportunity of thanking Dr. J. P. Bull and Dr. C. N. D. Cruickshank for their help in producing this article ; also Mr. J. R. Cooper for the microscopical preparations, Mr. N. R. Gill and his staff for the clinical photographs, Mr. F. Bradley for the photomicrographs, Sister E. Hitchens and Miss S. Timms for their assistance ; and Mr. W. Gissane, Clinical Director of the Birmingham Accident Hospital, for his interest and encouragement.

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THE SURGICALLY DAMAGED URETER

A METHOD OF URETERO-VESICAL ANASTOMOSIS

BY R. CAMPBELL BEGG AND P. J. DENNEHY

THE reimplantation of the severed ureter into any handy part of the bladder fundus has rarely proved a success. The ideal channel of entry from the physiological point of view is the normal one. It is true that this muscular tunnel is lined with the smooth mucosa of the lower end of the damaged ureter, and when the upper part is drawn through its external surface is not in contact with a raw area. This circumstance, however, as experience has shown, does not prevent firm organic union.

Patton (1939) did a service to surgery when he demonstrated the use of the existing passage to be not only desirable but also feasible, as in most cases the point of accidental division is just outside the bladder. He described an operation in which the upper segment of the cut ureter is isolated extraperitoneally and drawn into the opened bladder by means of a forceps passed out through the ureteric orifice. Millin (1949) has used this method with satisfaction, and one of us (R. C. B.) employed it successfully on two occasions. When the third suitable case presented itself, it was decided to use cystoscopic methods instead of opening the bladder.

CASE REPORT

Mrs. K., a European 53 years of age, underwent, on March 22, 1950, a Wertheim's hysterectomy on account of carcinoma of the cervix uteri. Unexplained rigors and high temperatures culminated on the seventh postoperative day in a burst of foul pus and urine from the

vagina. This was the first indication that the urinary tract had been injured. The customary tests excluded vesico-vaginal fistula. Excretory pyelograms demonstrated a normal left kidney and ureter, a secreting right kidney, but a break in the continuity of the right ureter with some pooling of urine just outside the bladder. Silk-web bougies inserted into the right ureteric orifice soon appeared in the vagina. A slough was removed from the right fornix, releasing about half a pint of stinking pus from an abscess in the pelvis.

Six weeks after the original operation, the ureterovesical anastomosis was undertaken after antibiotics and local treatment had improved the general condition.

the excavation. It was hooked up into the wound and the stylet withdrawn. By bringing the two ends of the catheter together and using the loop as a retractor, it could be seen that the ureter had been transversely and completely severed almost flush with the external bladder wall (*Fig.* 701).

It was necessary now to make a separate search for the upper segment, which doubtless lay embedded somewhere in the dense tissues of the wall of the abscess cavity. No spurt of urine betrayed its presence and the attempt to dissect it out or even to identify it proved fruitless. Recourse was then had to an intraperitoneal exploration, one of the existing tears being extended for

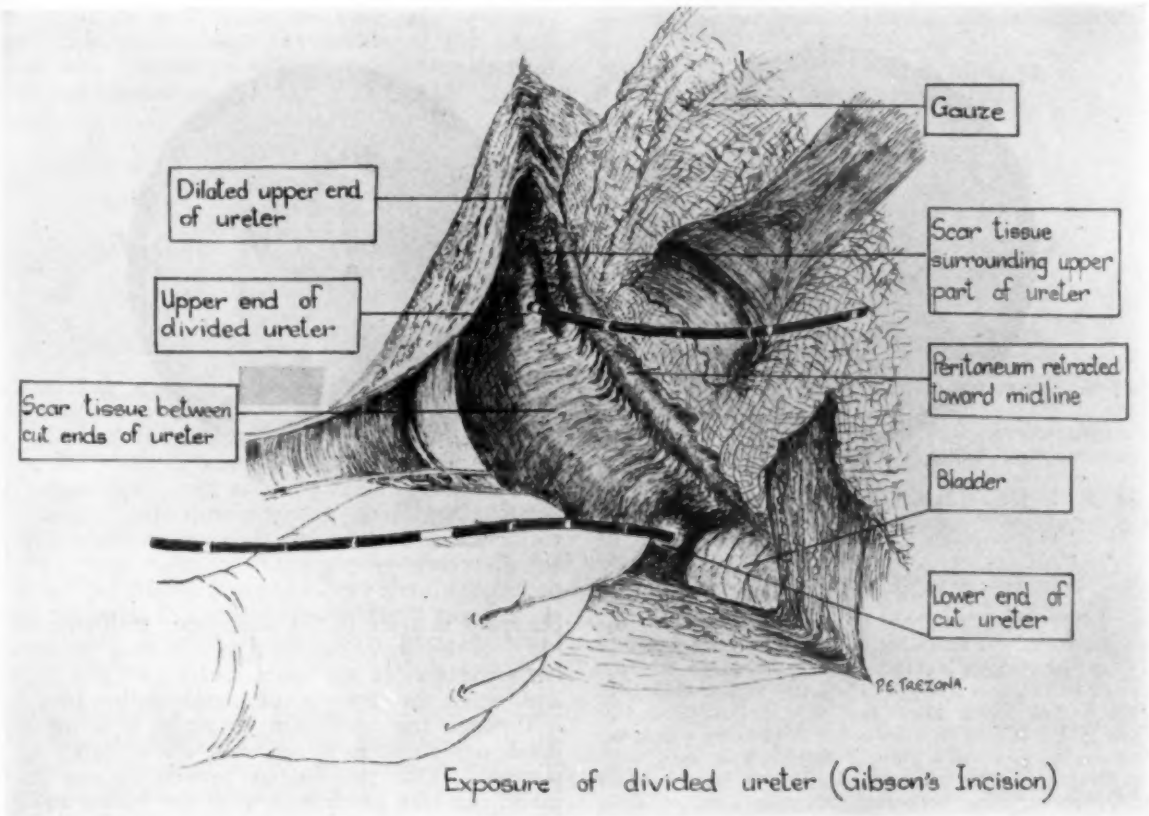
Gauze
Dilated upper end of ureter
Scar tissue surrounding upper part of ureter
Upper end of divided ureter
Peritoneum retracted toward midline
Scar tissue between cut ends of ureter
Bladder
Lower end of cut ureter
Exposure of divided ureter (Gibson's Incision)

FIG. 701—The ureter severed almost flush with the bladder wall.

THE OPERATION.—With the patient in the cystoscopic position a No. 8 F. round-ended silk-web catheter was passed for the short distance possible—about 6 cm.—into the right ureteric orifice. The rigidity imparted by a thick wire stylet prevented the catheter from turning the corner into the vagina, and enabled continuous pressure to be maintained during and after the withdrawal of the guiding panendoscope, thus keeping the point firmly in position. The patient's legs were then lowered, and draped individually to provide ready access to the catheter. A Gibson type of incision was made on the right side, and after the muscles had been incised, the arduous task of stripping off the peritoneum commenced. As usual in such cases, this procedure was beset with difficulties, cleavage planes being hard to find in the fused and matted tissues. Several rents were made in the peritoneum, and were utilized to insert a finger and guide the external dissection from within. Presently in the depths a space was opened which proved to be the reservoir from which the pus and urine had burst into the vagina. The end of the catheter pushed gently forward by an assistant was felt to emerge into this purpose. Finally the elusive organ was located as it crossed the external iliac artery. It was dissected out to the point where it entered the scar tissue and extraperitonealized by rolling it out and joining together the two leaves of the incised posterior peritoneum. Further sharp dissection secured another two inches from the scar tissue before the terminal opening was reached. The various rents in the peritoneum were darned and the ureter prepared for implantation.

A multiple-eyed No. 12 F. rubber ureteric catheter was passed as far as the kidney pelvis. The ureter was fixed to it by a tight circular silk ligature as in the Coffey No. 2 operation, a cuff about a centimetre in length remaining distal to the tie. An assistant reinserted the stylet into the original silk-web catheter, thus giving it a rigidity which enabled the rubber catheter, which was of larger bore, to be threaded over it, as over a probe. Both catheters were withdrawn and the silk-web one detached and discarded. Gentle traction on the rubber one brought the upper segment of the ureter through the canal into the bladder, where it was adjusted in such a way that about a centimetre of it projected into the

cavity. It was fixed in this position by two sutures joining it to the external wall of the bladder at the site where it entered.

It would have been possible to have concluded the operation at this point by introducing a self-retaining urethral catheter and attending to the wound. In view of the extreme sepsis, however, and to avoid irritation of the trigone, a malécot catheter was inserted by means of a stab wound, so as to establish suprapubic drainage. This precaution was probably unnecessary. The final step was to sew up the wound with a Penrose tube down to the site of the anastomosis.

POST-OPERATIVE COURSE.—The rubber ureteric catheter emerged from the urethra and drained the right kidney, while the urine from the left came through the suprapubic tube. The quantities were about equal and there was no urinary leakage. On the seventh day the rubber catheter came away, bearing its tubular slough of ureter. A few days later the suprapubic tube was removed and replaced by a trans-urethral Foley's catheter attached to a Stedman's pump. After all wounds were healed this was removed and the patient passed water without difficulty and with full control. The discharge of pus from the vagina gradually ceased and the infection in the urine responded well to chloromycetin. It flared up again when deep therapy was begun, but rapidly improved when this form of treatment was discontinued.

CYSTOSCOPIC APPEARANCES.—The examination was made five weeks after the operation. The right side of the trigone was drawn up and the reimplanted ureter protruded with rolled edges, like a corn-plaster or miniature lifebuoy dropped on to inner surface of the bladder (*Fig.* 702). A leash of blood-vessels radiated from the new orifice, and peristaltic movements, indistinguishable from those normally observed, took place at intervals. Indigocarmine, injected intravenously, appeared from the left side in five minutes and from the right in twelve. The concentration was good in each case. A catheter passed freely to the right kidney pelvis. The urine from this side was moderately infected.

FOLLOW-UP.—The patient was discharged on June 5, six weeks after the operation, the delay being chiefly due to the measures taken to overcome sepsis. She was lost sight of for a while, but looked in on July 31, 1951, fifteen months after the operation, to say how well she was. She was unable to wait to be examined, but mentioned that the urinary function was normal and the vaginal discharge had ceased.

FIG. 702.—Showing the rolled edges of the implanted ureter.

COMMENT

The use of a catheter made rigid by a stylet has several advantages and facilitates the operation. In cases such as that described, in which the ureter has been completely divided, it stands out as a beacon leading the operator directly to the lower segment. When the upper component is found it can be brought into the bladder with less trauma than with forceps. Its presence during the early part of the operation in the transvesical ureter has the effect of relaxing the muscular walls of that corridor, thus permitting the reception of the new occupant in spite of the continuing residence of the old. If the ureter has been merely tied, the catheter leads the way to the exact location of the ligature, and, when the latter is cut, manipulation may carry it through the restriction to act as a splint and a drain while nature is restoring the integrity of the passage. This process, as proved in one of our cases, can take place even after the lumen has been firmly and tightly occluded for six weeks. If there has been only a partial severance, the presence of the catheter enables the ureter to be quickly found, repaired, and splinted or reimplanted into the bladder as indicated.

It is, of course, necessary to cut off the loop of the stylet to enable it to pass through the introducing instrument. The ordinary beaked cystoscope is hardly suitable as it tends to pull the catheter out of the shallow ureteric stump when it is being withdrawn. If a panendoscope is not available it may be necessary for a colleague to do the cystoscopic work after the open exposure has been made, the surgeon grasping the catheter from within as the cystoscopist pushes it from without. This is, however, rather an awkward business for both, necessitates more movement of the patient, and might be liable to upset the strict aseptic technique.

Care must be taken that the ureter projects the right distance into the vesical lumen, as it is impossible to observe it from within as in cases where

the bladder is opened. By touch and estimating the amount the rubber catheter has been withdrawn from the urethra after the end of the ureter begins to enter the bladder, it is possible to make an exact enough estimation.

The new ureter is, of course, several centimetres shorter than the old. A very considerable truncation is, however, by no means incompatible with a successful result. Indeed, a muscular tube has no more a fixed length than a migrating earthworm, which becomes thinner and longer and then thicker and shorter as it goes on its way. The use of the rubber catheter tends to prevent the ureter pulling itself out of its new bed in the early post-operative stages. Later the tonus or posture of the longitudinal and circular muscle-fibres adjusts itself to the altered conditions.

SUMMARY

An accidentally severed ureter should, if at all possible, be reimplanted into the bladder through the existing channel.

While the ureter may be inadvertently *ligatured* at any point of its pelvic course, it is usually *cut* close to the bladder wall. Thus by means of the slack gained by eliminating the pelvic curve, together with the power of tonic lengthening inherent in the organ itself, the anastomosis is feasible in the majority of cases.

A simplified method of carrying out the operation is described.

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MEDIASTINAL GASTRIC CYST PRESENTING IN THE NECK

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MEDIASTINAL cysts which are lined with gastric mucosa are a well-recognized clinical entity. The first case was recorded by Staehelin-Burckhardt in 1909. With the advance of radiological and surgical techniques these cysts are now encountered increasingly often and knowledge of their pathological features assumes practical importance in diagnosis and treatment. An excellent survey was made by Davidson and Brown (1947). More recently, Bickford (1949) reviewed the subject and added 2 cases of his own. In all, at least 32 cases have been recorded and the natural history of the condition is well established.

The following case presents certain bizarre features and nothing similar has been found in the literature. The cyst, which was lined with gastric mucosa, arose in a typical position in the upper mediastinum, but it presented clinically as a swelling high in the neck. Interest lies not only in its rarity, but in the illustration of possibilities which may arise if there is functional activity (with secretion of acid) of the lining mucosa.

CASE REPORT

Janet O. was born on Nov. 10, 1944, and first attended hospital in May, 1946, with a painless swelling in the right side of the neck. The swelling was situated just below and behind the angle of the mandible and was thought to be an enlargement of one of the glands of the upper deep cervical chain. It failed to subside after removal of her tonsils and adenoids. She was admitted to hospital, under the care of the late Mr. J. B. Hunter, in January, 1948.

Her general condition was good.

Horner's syndrome on the right side was present and had first been noticed in June, 1947.

The swelling on the right side of the neck was 1½ in. long and 1 in. broad, with its long axis passing downwards and forwards from just below the mastoid process to 1 in. above the clavicle. Its posterior part was deep to the sternomastoid muscle. It was cystic, but not translucent, and did not empty on pressure. It was not attached to skin or deep structures.

There were no other abnormal physical signs.

At this time a diagnosis of cystic hygroma was considered most likely.

AT OPERATION (Jan. 13, 1948).—Mr. J. B. Hunter exposed a thick-walled cyst through a horizontal incision in the upper part of the neck. The cyst was opened and a prolongation admitting the tip of the index finger was found to extend downwards into the thoracic inlet. A second incision above the clavicle was then made and dissection of the mediastinal prolongation was continued extrapleurally in the paravertebral groove down to the level of the second rib posteriorly. A fibrous cord was found passing downwards to the back of the hilum of the lung: this was clamped and the cyst removed.

FIG. 703.—Photomicrograph of the mediastinal part of the cyst showing typical features of stomach wall with mucous membrane and muscle layers. (× 5.5.)

The post-operative course was uneventful and she was discharged from hospital on Jan. 27. A barium swallow done after discharge from hospital showed a normal œsophagus.

PATHOLOGICAL REPORT (Prof. H. A. Magnus).—The specimen consists of an elongated cyst 6 cm. in length; it has been opened. The greater part of its wall is thin and fibrous and no lining membrane can be made out,

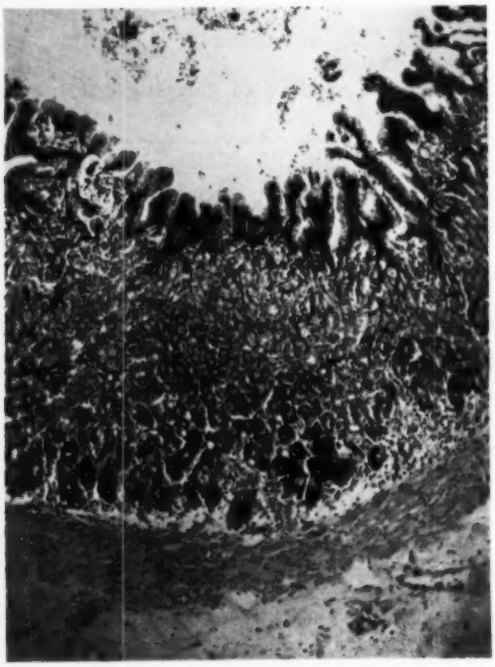

FIG. 704.—Photomicrograph showing typical gastric mucosa as normally found in the body of the stomach. (× 112.)

but at one point the cyst wall is 0·5 cm. in thickness and contains a distinct muscular layer; here a uniform velvety lining membrane is present. (*Fig.* 703.)

A section through the thickened area of the cyst wall shows a well-developed gastric mucosa of the acid-bearing area of the stomach. This is resting on a muscularis mucosæ beneath which there is submucosa and then a well-developed muscle layer. (*Fig.* 704.)

A section of the finer part of the wall of the cyst shows no cellular lining, merely some rather vascular granulation tissue lying on muscle.

DISCUSSION

At least 30 cases of gastric mediastinal cysts have been recorded in the literature, but in none has the swelling extended into the neck.

The aetiology has been frequently discussed, but no definite conclusion has been reached and this present case has no features which help to elucidate the problem. It may, however, be pointed out that while it is correct to include these cysts under the general classification of reduplication of the gut, there can be no simple mechanical factor which will explain the ectopic development of any particular mucosa. Any theory must explain how a cyst in the tongue comes to be lined with colonic mucosa, while a cyst lying near the rectum can be lined with gastric mucosa, as reported by Ladd and Gross (1940).

Of more particular interest as far as the present case is concerned is the question of functional activity of the gastric mucosa. The presence of hydrochloric acid in the fluid contents is not often recorded, particularly when the diagnosis is unexpected and only made on histological examination (as in the case reported here). It is, however, possible to presume activity if an ulcer (typical in structure of a chronic gastric ulcer) is found in the cyst wall. This has been reported in at least 4 cases (Schwarz and Williams, 1942; Brass, 1936; Seydl, 1938; and Dickson, Clagett, and McDonald, 1946). In a further case (Valle and White, 1946) no ulcer was demonstrated, but it was thought that one had been present since the cyst was eroding the right lower-lobe bronchus. Ulceration may also occur into the lung parenchyma or even into the bodies of adjacent vertebræ and ribs (Ladd and Scott, 1944). It is estimated that acid secretion probably takes place in about a third of gastric mediastinal cysts. Functional activity and the presence of an ulcer may possibly account for the bizarre presentation in this case. It may be presumed that the cyst arose posteriorly in the upper mediastinum and that the swelling in the neck resulted from the slow perforation of an ulcer tracking upwards and becoming walled off by fibrous tissue. The presence of dense adhesions around the cervical part lends support to this conjecture.

Our thanks are due to Professor H. A. Magnus for his pathological report.

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HYDRONEPHROSIS IN CHILDREN

A CLINICAL STUDY OF SEVENTY-EIGHT CASES WITH SPECIAL REFERENCE TO THE ROLE OF ABERRANT RENAL VESSELS AND THE RESULTS OF CONSERVATIVE OPERATIONS

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THE association of 'aberrant' renal vessels with hydronephrosis was described as long ago as 1842 by von Rokitansky. Post-mortem studies such as those of Eisendrath and Rolnick (1942) have shown that variations in the course of the renal vessels are common in normal people and that true lower polar vessels are found in as many as one in sixteen kidneys. Their importance as an aetiological factor in hydronephrosis has been debated at length. It was hoped that the study of a consecutive series of hydronephroses, including many treated by operations to conserve the kidneys, may throw further light on the role of the vessels and on the clinical value of such procedures.

The material consists of 78 treated hydronephroses occurring in 77 patients of the Hospital for Sick Children, Great Ormond Street, during the period January 1929 to August, 1950. It is realized that the records of the earlier years are incomplete owing to war-time losses, but there has been no other selection of cases. The majority of the operations were performed by Mr. T. Twistington Higgins, and I am indebted to him and to other members of the staff for access to their cases.

Conservation of the kidney had been attempted in 46 cases. Some of these had undergone recent examination. The remainder were examined clinically and by intravenous pyelography. The period of follow-up varied from 6 months to 22 years, as shown in *Table I*.

Table I.—PERIOD OF FOLLOW-UP OF CONSERVATIVE OPERATIONS

Over :	1	2	5	10	15	20 years
No. of cases	34	30	12	5	2	1

6 came to secondary nephrectomy; 1 not traced; 5 under 1 year.

Of the successful conservations only 1 of the vessel obstruction cases (which was clinically well 5 months after operation) could not be traced. Pyelographic follow-up was not considered practicable in 5 of the clinically satisfactory cases without abnormal vessels, but it was considered that an adequate group had been obtained for comparison.

For the purpose of the analysis the cases have been divided into three groups: First, those in which renal vessels appeared to have been contributing to the obstruction; second, those with an organic stenosis of the region of the pelvi-ureteric junction; and third, those in which bands or adhesions caused 'fixation' of the junction (*Table II*).

Finally, in 5 cases no convincing cause was found and in 4 no cause was recorded.

Only those instances of primary hydronephrosis in which the obstruction appeared to be at the pelvi-ureteric junction region have been included. Lesions which were merely secondary to mega-ureter have been rejected, although 4 cases in which junction obstruction requiring treatment coexisted with mega-ureter have been retained (all in the fixation group).

Table II.—CLASSIFICATION OF CASES

	Total	*Infected*	*With Calculi*
Group I : Vessel Obstruction	25	9	4
Group II : Stenosis	25	11	3
Group III : Fixation	19	11	1
Remainder : Cause doubtful	9	4	0

Post-infective dilatations of non-obstructive origin have likewise been rejected, as have distensions secondary to calculus disease or tumour.

THE CLINICAL PICTURE

Text-books usually describe the typical course as being an insidious one and relate this to the presence of 'closed hydronephrosis'. A less common group with severe attacks of renal colic is described as resulting from 'intermittent hydronephrosis'. The main clinical features of this series are presented in *Table III*.

Table III.—CLINICAL PICTURE

	Group I (Vessel)	*Group II (Stenosis)*	*Group III (Fixation)*	*Remainder (? Cause)*
Total Number	25	25	19	9
Attacks of pain	23	18	13	9
Vomiting	16	17	7	4
Headache	3	2	0	1
Puffy face	1	2	0	1
Micturition—				
Normal	14	14	13	4
Frequent		1	3	2
Misc.		4	2	2
Urine—				
Clinical hæmaturia		5	2	2
Clinical pyuria		3	2	2
Hypertension		1	1	0
Kidney—				
Palpable	1	4	3	3
Tender		1	2	1
Contralateral kidney lesion	3	2	2	2
History longer than 2 years		—— inadequate notes ——		
Side affected, L : R	17	19 : 6	15 : 4	7 : 2

* 2 contralateral hydronephroses only became recognizable during follow-up after operation.

It will be seen that in the vessel group attacks of pain were the presenting symptom in 92 per cent. In one of these cases which began in infancy pain was not specifically recorded, and in one older child it was definitely absent throughout—in spite of an associated mobile pelvic stone!

In those cases without vessels only 73 per cent were painful. An insidious course was found in several cases which proved to have an incomplete obstruction to the urinary outflow. The acute episodic course appeared rather to depend on the

superimposition of attacks of acute obstruction on a chronic obstruction of varying degree, as will be discussed below.

The attacks have usually lasted from a few hours to one or two days and have occurred at monthly or even weekly intervals. Often their severity and frequency had increased shortly before admission. The pain was commonly felt in the side and similar to the adult's ' renal pain ', though with little tendency to radiate. It was severe enough to cause vomiting in the majority. In four it was ill-localized and may have led to clinical suspicion of an alimentary origin. In three it was in the right iliac fossa and had led to two unhelpful appendicectomies.

Micturition was usually normal, as might be expected in a lesion of the upper urinary tract. Increased frequency was present in 13 cases and was usually attributable to infection. Hæmaturia was almost as common, being found in 11 cases. Only 1 patient had the classical oliguria with pain followed by polyuria with relief.

Headache was complained of in 6 cases, and it is interesting to observe that one of these cases was hypertensive, another had a transient post-operative hypertension, and a third (aged 10 years) had a borderline pressure of 115/90 at follow-up. In 2 the blood-pressure was not recorded and in only 1 was it definitely normal throughout.

The great majority of the children were in good health between the attacks. Complaints of listlessness, anorexia, irritability, and poor gain were made in only 11 cases.

The story was usually a long one before full investigation led to operation. It was more than two years in half of the vessel cases, there being insufficient data in the other groups for comparison.

The past histories revealed no obviously significant factors. A high proportion of upper respiratory disease was probably normal for a mainly urban group.

The family and social histories were often sketchy, but no positive evidence of familial hydronephrosis or environmental factor could be traced.

The preponderance of left-sided lesions—58 to 20—was unexpectedly high, although the tendency has been noted in other reported series. It was present in all groups.

There was no significant sex incidence and the cases were evenly spread throughout the age range served by the hospital (0–12 years).

Physical examination usually revealed no abnormality (though many were not seen during an attack). The kidney was palpable in a quarter of the cases. Puffiness around the eyes was observed in 4 cases, and when it was associated with hæmaturia it led to clinical suspicion of nephritis in 2 cases.

Hypertension was present in 3 cases, 1 infected and 2 sterile. In the first (aged 5) the pre-operative pressure of 150/105 continued to rise after a conservative operation but settled to 120/80 seven months after nephrectomy. The second case (aged 4) had a pre-operative pressure of 160/120 which came down to 130/80 under resting conditions. Nephrectomy was performed and the pressure was 110/65 a month later. In both cases the kidneys showed severe ' pyelonephritic ' changes. The third case had a pre-operative pressure of 150/110. He recently had the kidney removed and his post-operative progress has not been assessed.

The severity of the hydronephrosis, estimated as gross, moderate, or small, as seen on pyelography, is shown in *Table IV*.

Table IV.—DEGREE OF HYDRONEPHROSIS

	Gross	*Moderate*	*Small*	*? (early films not available)*
Group I (Vessels)	9 (6)	15	1	0
Group II (Stenosis)	13 (8)	7 (1)	0	5 (2)
Group III (Fixation)	11 (5)	3 (1)	0	5

Figures in brackets denote number treated by primary nephrectomy.

Pyelography revealed a contralateral renal abnormality in 11 cases—about 14 per cent. In 9 cases this was a symptomless hydronephrosis (2 of which only appeared during the follow-up period). One child had a contralateral double kidney and another had a grossly elongated and narrowed upper calix.

In 8 cases calculi had formed, but were believed to be secondary to stagnation in the hydronephrotic kidney (*see Table II*).

DISCUSSION

The clinical picture has usually been typical, with attacks of pain in the side often causing vomiting. Nevertheless the diagnosis was often delayed until the symptoms had persisted for two years or more. It seems that the delay was occasioned less by any unusual features in the case than by the fact that the child when seen, as was usual, between the attacks, was in good health with no physical signs. One hesitates to encourage further investigations, but it should be emphasized that the absence of clinical signs and the presence of a normal urine do not exclude an obstructive uropathy. Nor need one expect disturbance of micturition in disease of the upper urinary tract. Faced with an unexplained pain in the side a pyelogram is a necessary investigation. Although this may seem obvious, the length of the histories in this series shows that investigation has been delayed—and hence the chance of retaining the kidney lessened.

We have not found the ' gastro-intestinal disturbances ' as frequent as Meredith Campbell (1951), and it would seem that he has had a larger proportion of grossly infected cases in which the symptoms of infection have overshadowed those of the underlying hydronephrosis.

The cases associated with apparently obstructing vessels appear to form a clinically distinct group in which a history of attacks of severe pain was almost invariably present. In only one case was pain definitely absent throughout the clinical course of the disease. In those cases without obstructing vessels, however, a quarter had a painless course. This is in accordance with the findings of Hellström, Giertz, and Lindblom (1949) in their study of 100 cases.

THE FINDINGS AT OPERATION

Group I (with Apparently Obstructing Vessel) (25 cases).—

The Pelvi-ureteric Junction.—In exposing the organ at operation careful freeing of the junction is

always necessary. Some anomaly worthy of note apart from the vessel was described in 16 cases. In 11 there was adherence of the ureter to the pelvis; in 5 there was kinking of the upper end of the ureter by bands, but intrinsic stenosis of the lumen was only mentioned twice. In only 4 of these cases was the urine infected, and there is thus no evidence of an infective origin of the 'adhesions'. It is rather thought that they are of congenital origin, as discussed below. (*Fig.* 705.)

The Course of the Vessels.—The vessel passed anterior to the junction region in 13 cases, posteriorly in 6, and its relation was not recorded in 6. Only in 10 cases were the vessels recorded as being truly lower polar vessels, and many were definitely entering the hilum at its lower part.

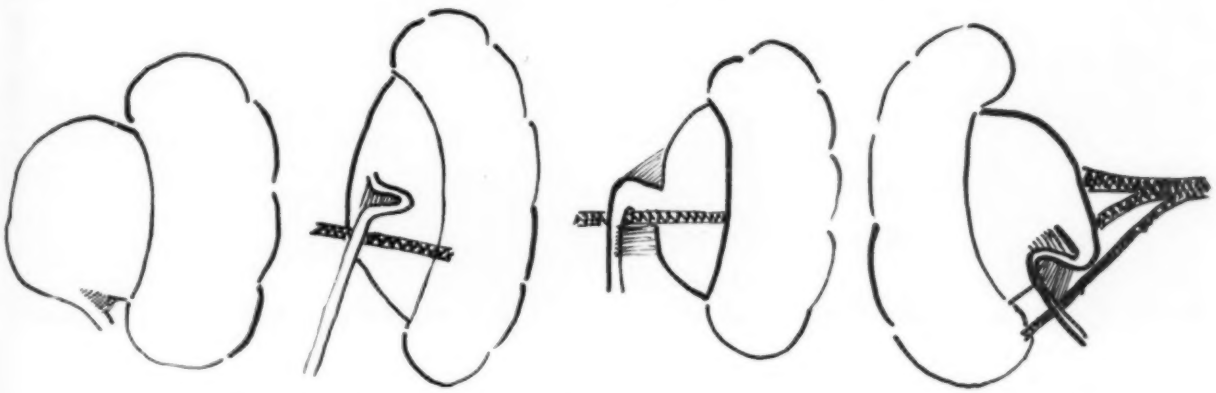


FIG. 705.—Reproductions of four of the sketches of 'fixation' of the ureter made at the time of the operations.

Evidence of Obstruction at a Lower Level than the Junction.—In 22 there was no evidence of abnormality lower in the urinary tract. One case had a slight dilatation of the ureter which had become more marked on pyelography three years after a successful operation, suggesting some abnormality lower in the tract.* Another case had an abnormal ureterovesical orifice, which, although it looked normal at rest, opened very widely with urinary efflux. On the other side this child already had a frank mega-ureter with a similar orifice at its lower end. A third case had a stenosed ureterovesical orifice which may have been the result of prolonged infection.

The Type of Hydronephrosis.—In 14 cases where the available records and photographs were adequate the hydronephrosis was mainly pelvic in 9, or of combined type in 8, and only in 1 case were the calices mainly affected. This proportion would appear reasonable, as the type of kidney pelvis which is mainly extrarenal would be expected to be more prone to meet an extrinsic obstruction such as an abnormal vessel.

Operative Observations.—Dramatic emptying of the pelvis on removing an obstruction was recorded as occurring 9 times in this group. In 4 cases it took place when the vessels were divided, but in 5 division of the 'adhesions' was also necessary. One of these cases required a secondary nephrectomy for progress of a pre-existing hypertension. Clinically and pyelographically all the others have done well, including 3 observed for between ten and twenty-two years. It would seem that this prompt emptying at operation may be of value in assessing the prognosis.

Group II (with Intrinsic Stenosis) (25 cases).—The stenosis typically occurs at the upper end of the ureter or extends into the pelvi-ureteric junction itself. After stripping the region a spasm will often give the appearance of stenosis. However, passage of bougies by a pyelotomy incision distends the normal junction. A true stenosis will split if dilatation is persisted in. It can be observed during this manœuvre that the stenosis is usually due not to scarring but to a deficiency in the muscle coat associated with a mucosal narrowing. (Higgins and others, 1951.) Adequate histological examinations have not been made in this series, but the fact that 14 of this group had a sterile course is further evidence against an infective origin in the majority of cases.

In 9 cases folds or bands fixing the upper ureter coexisted.

Group III (Fixation of the Ureter only) (19 cases).—The connective-tissue folds fixing the upper end of the ureter varied from a loose 'sail-shaped adhesion' to a firm short band. The ureter was held against the pelvis during distension, producing a kinking obstruction of the outlet which could easily be missed on examining the pelvis in a collapsed state. It was not uncommon for the fold to be vascularized with a small branch from the renal vessels running along its border. Such vessels ended by breaking up in ramifications over the surface of the pelvis and perhaps of the kidney itself. They were not considered under the heading of aberrant renal vessels and were obviously of no intrinsic significance.

The folds were continuous with the connective tissue cloaking the ureter and pelvis, of which they appeared to be a derivative.

Evidence of inflammatory reaction was usually lacking and the fixation was similar in early and

* Pre-operative pyelograms not infrequently showed some dilatation of the ureter. At operation it would be seen to contract normally and after operation to maintain a normal calibre on pyelography. This was thought to be disuse atony—the 'slacking ureter' of Higgins, Williams, and Nash (1951).

uninfected cases to that in late and infected ones (11 out of 19).

THE OPERATIONS PERFORMED

Group I (Vessels).—Ligature and division of the obstructing vessels was carried out in 16 cases. Division of fixing 'adhesions' was also noted as being required in 13. In 4 a complicating calculus was removed by pyelolithotomy. In 2 an organic stenosis also required a plastic widening. In 4 a wedge was excised in addition, to reduce a large flabby pelvis.

In 3 more recent cases the Hamilton Stewart (1947) manœuvre has been successfully carried out to remove the vessel from the region of the junction without necessitating its division. Adhesions were noted as requiring division in 2 of these.

Primary nephrectomy was carried out in 6 advanced cases.

Group II (Stenoses).—In 14 a conservative operation was performed. In 7 this consisted of a Heinecke-Mikulicz type of plastic widening of the region by transverse suture of a longitudinal incision (2 of these required pyelolithotomy in addition). In 6 the junction region was resected and the ureter reimplanted. Three of these were combined with partial pelvectomy in the manner of Lichtenberg. In 1 case dilatation alone appeared to suffice (though the result was eventually unsatisfactory).

Primary nephrectomy was performed in 11 advanced cases.

Group III (Fixation).—Conservation was attempted in 13 cases. In 12 the procedure was simple division of the 'adhesions'. In 2 this was complemented by nephropexy. In 1 case it was necessary to resect the firmly fixed junction and reimplant the ureter. Occasionally the end of the fixed ureter is found to pass obliquely through the muscle layers of the pelvic wall requiring division of this muscle to reveal the true pelvi-ureteric junction (Hellström, 1927).

In 6 cases primary nephrectomy was required.

THE RESULTS OF CONSERVATIVE OPERATIONS

The results of the attempts at conservation are tabulated in *Table V*. In order to assess these figures it is necessary to have some idea of the natural course of the disease. For obvious reasons clinically recognized cases are rarely followed for long without intervention. However, Hellström and others (1949) have followed 31 cases not operated on for various reasons. In only 7 cases did the demonstrable lesion progress under observation for periods of one to fourteen years. In 24 it was approximately unaltered. A case was quoted to show that recurrent attacks of pain are not necessarily associated with deterioration of the kidney, and others to show that on the contrary clinical silence may be associated with progressive deterioration.

It will thus be seen that a clinical follow-up is of itself valueless and that pyelographic improvement must be demonstrated as evidence of relief of obstruction.

Our figures confirm the general observation that operation is likely to relieve pain in most cases, whether or not the obstruction has been overcome. In only 2 cases did pain persist after operation. This phenomenon has been attributed to unintentional sympathectomy during clearance of the organ at operation. In view of the difficulty of obtaining complete sympathetic denervation deliberately in other regions it is surprising that one should be so consistently successful by accident. It would seem that a simpler mechanical explanation is at least a possible alternative. The pain is caused by attacks of acute distension of the pelvis. Any thorough freeing of the kidney is followed by the production of fibrous adhesions around the organ, as can be observed at secondary operations. By preventing acute crises of distension these may well prevent pain even though back-pressure with its ill effects on the parenchyma persists.

Table V.—Results of Conservative Operations

	Total Cases	Conservation Attempted	Clinical Relief	I.V.P. Review			Not Done	Follow-up			Secondary Nephrectomy
				Improved	ISQ	Worse		1 yr.	5 yr.	over 10 yr.	
Group I (Vessels)	25	19	17	16	2	0	1	15	7	3	2
Group II (Stenosis)	25	14	11	6	0	1	4	11	3	1	3
Group III (Fixation)	19	13	9	4	3	4	1	8	2	1	1

Conservative operations	46
Success (i.e., pyelographic improvement and clinical relief)	26
Secondary nephrectomy	6
Pyelograms ISQ or Worse, but symptomatic relief	8
No follow-up pyelogram	6

By the more trustworthy criterion of pyelographic improvement, it will be seen that there is a great difference in the results in the different groups.

Those cases associated with obstructing vessels have been successfully conserved in 64 per cent of the total 25 cases. Of those cases in the fixation and stenosis groups which have had pyelographic follow-up or have come to nephrectomy only 26 per cent were successfully conserved. Even if all those cases which did not have a pyelographic review were assumed to have improved, the successes could only rise to 34 per cent.

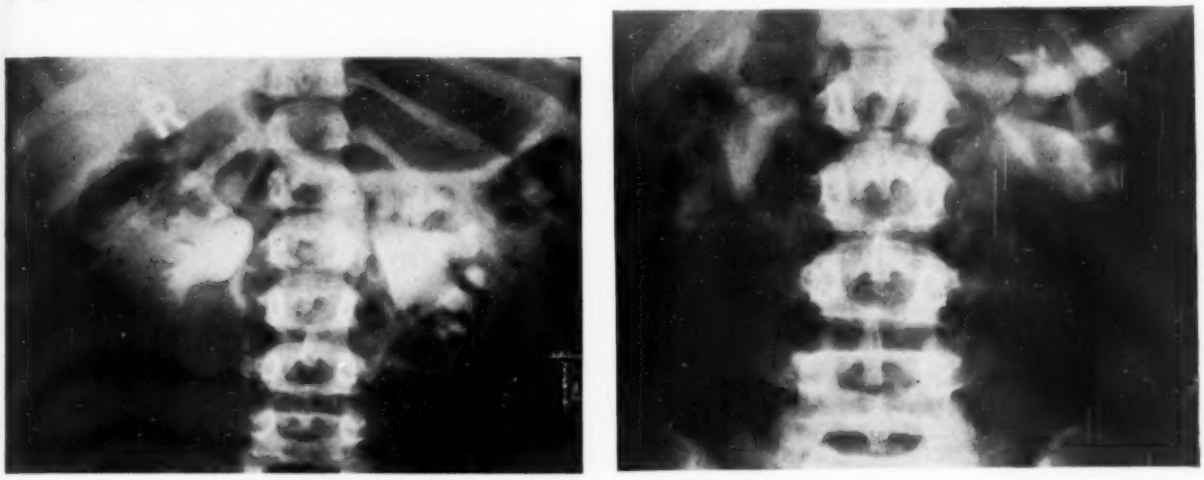
Thus the chances of successful conservation were doubled when an obstructing vessel was present.

A difference again exists in the proportion of successes among those cases in which conservation was attempted. Operations for cases with vessel obstruction succeeded in 89 per cent (of 18 adequately followed out of 19 operations); for those with stenosis in 60 per cent (of 10 adequately followed out of 14 operations); and for those with fixation only in 33 per cent (in 12 adequately followed out of 13 operations).

The successes are least frequent in the fixation group, where the operation of adhesiolysis is technically the most simple—and indeed was usually carried out in addition to the other procedures required in the vessel group. The difference, therefore, cannot be attributed to variations in technical difficulty.

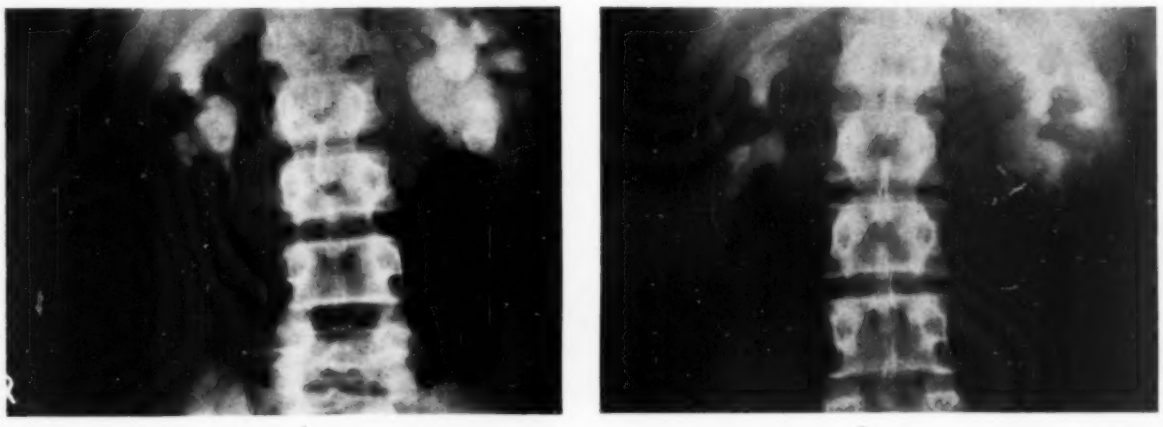
The degree of pyelographic improvement in the followed successful cases is shown in *Table VI* and *Figs.* 706–709. In only one patient did the pyelogram become quite normal. However, relief of obstruction is the aim rather than restoration of anatomical normality, which cannot be expected to occur after the considerable structural changes which take place in the hydronephrotic kidney.

Six cases came to secondary nephrectomy. One was a 5-year-old boy with a *B. coli* infection and hypertension of 150/105 before operation. Five months after operation the urine remained sterile, but his blood-pressure had risen to 170/120 (with amytal sedation) so nephrectomy was undertaken, revealing a kidney with a gross aseptic pyelonephritis. Seven



A B

FIG. 706.—*Case* 20. Two years' history of attacks of pain in left side causing vomiting. A, Pre-operative I.V.P. shows small left hydronephrosis (and slight dilatation on the right side). Aberrant vessel divided and fixation of pelvi-ureteric junction freed. B, I.V.P. one year after operation shows marked improvement but contralateral dilatation persisting. Patient well and symptomless (*see footnote*, p. 607).



A B

FIG. 707.—*Case* 13. Two years' history of attacks of pain in left loin causing vomiting. A, Pre-operative I.V.P. shows moderate left hydronephrosis. Aberrant renal vessel divided and fixation of pelvi-ureteric junction freed. B, I.V.P. four years after operation shows a normal pyelogram. Patient well and symptomless.

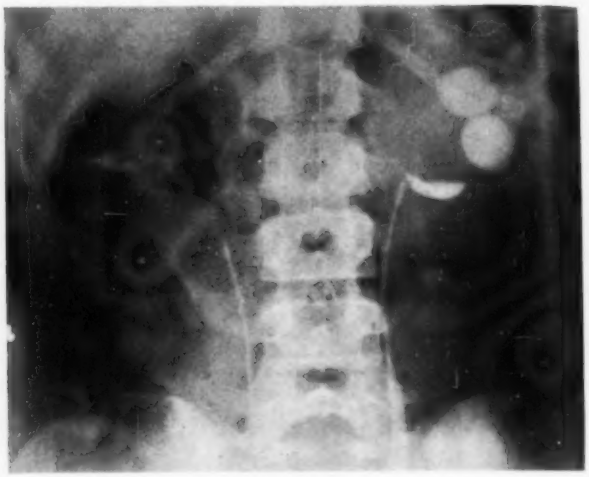
Table VI.—DEGREE OF PYELOGRAPHIC IMPROVEMENT IN SUCCESSFUL CONSERVATIONS

	Normal	*Much Improved*	*Improved*	*Slightly Improved*
Group I (Vessels)	1	4	9	2
Group II (Stenosis)	0	0	3	2
Group III (Fixation)	0	1	3	0

months after this second operation his blood-pressure was reduced to 120/80 and he was clinically well.

A second had Proteus infection and calculi, both of which recurred after conservation. The kidney was grossly pyelonephritic.

A



B

C

FIG. 708.—*Case* 45. Six months' history of attacks of pain in left loin, vomiting, and frequent micturition. A, Pre-operative I.V.P. shows no excretion on left side. B, Pre-operative retrograde pyelogram shows dilated calices of a large hydronephrosis. At operation a firmly fixed ureter was found, though the pelvi-ureteric junction was patent. The junction was resected and the ureter re-implanted. C, I.V.P. two years after operation shows marked improvement. Good secretion and restoration of normal caliceal pattern. Patient well and symptomless.

The third was a girl who had had a previous unsuccessful attempt at pyeloplasty elsewhere with prolonged drainage. She also had a patent ductus arteriosus. *B. coli* infection of the urine persisted and the other kidney was hydronephrotic. Conservation was attempted in view of the serious outlook, but secondary hæmorrhage necessitated urgent nephrectomy.

The fourth was also an infected case in which recurrence of *B. coli* infection with constitutional symptoms necessitated the removal of a flabby kidney with marked perinephritis.

In the fifth case the operation failed to relieve the attacks of pain in a sterile case and nephrectomy was required.

FIG. 709.—*Case* 1. Two years' history of pain in left side, continuous with severe attacks accompanied by vomiting. Retrograde pyelogram showed left hydronephrosis (took 18 c.c. dye compared with 6 c.c. on right side). Films not available. Aberrant renal vessel divided and fixation of pelvi-ureteric junction freed. Patient has been well and symptomless since, and served overseas in the Army during the last war, graded A1. I.V.P. was taken sixteen years after operation.

The sixth was another case in which uncontrolled infection necessitated removal of the kidney.

It will be seen that secondary nephrectomy has usually been required because of failure to control complications of the hydronephrosis, such as infection. Several cases with symptomless but unrelieved hydronephrosis have not yet come to nephrectomy, and one patient who had recurrence of colic a few months after operation has not been further traced.

In general it has been observed that pyelographic examination about three months after operation is a good prognostic guide. Any improvement seen at this time has been maintained, but there has been little evidence of further delayed pyelographic improvement, regardless of symptomatic relief.

THE PLACE OF CONSERVATIVE OPERATIONS IN TREATMENT OF HYDRONEPHROSIS

Nephrectomy will cure hydronephrosis with a negligible mortality, and the absence of one kidney is no handicap if the other be normal. Why then should conservation be attempted?

In cases in which the condition is already bilateral the answer is obvious. Seven of these patients had a contralateral dilatation. Perhaps more important, two more have developed an as yet symptomless hydronephrosis on the other side since operation. In the usual unilateral case, however, the risk of future disease or injury of the opposite kidney may be slight in older patients. The risk will increase as the patient's age decreases. At the ages of these children it has been considered sufficient to justify attempts to save kidneys which must have suffered considerable parenchymal damage.*

Further, if conservative surgery is to be justified it must be reasonably free from risk. There has been no mortality in this series and only one serious post-operative complication. This was the secondary hæmorrhage already mentioned, which occurred in a patient who was realized to be a greater though justifiable risk. The other 5 secondary nephrectomies were carried out as planned procedures when observation had shown the attempt at conservation to have failed.

To these risks must be added the longer-term risk of hypertension. It has been shown by Platt and Davson (1950) and others that uncomplicated hydronephrosis can produce hypertension. The great reduction in blood-supply has been demonstrated by Levy, Mason, Harrison, and Blalock (1937), Trueta, Barclay, Daniel, Franklin, and Pritchard (1947), and others. Thus the retention of an impaired kidney may carry this risk.

Division of an aberrant artery is unlikely to produce this complication. Owing to the distribution of the vessels as end-arteries the damage is local and the involved segment is likely to atrophy completely, so that the venous return is negligible and the necessary prolonged partial ischæmia does not occur. At all events alternative procedures are now in use to avoid division of the vessels, such as Hamilton Stewart's manœuvre, Hellström's (1934) 'transplantation' of the vessel, or reimplantation of the ureter away from the vessel as practised by Quinby (1927) and Patch (1929).

Bergendal's (1936) impressive follow-up of 62 cases of vessel section for periods up to 29 years would appear to be the only adequate survey conducted with these long-term risks in mind. Six of his adult cases had developed a raised blood-pressure but the relation to the operation was uncertain. The risk thus seems to be slight. In this series no patient has developed hypertension after conservative operation, but the follow-up is short in relation to this insidious disease in most of the cases.

Suitability of Cases for Conservation.—In the development of hydronephrosis the significant changes may be considered in two classes. First, there is the enlargement of the pelvis. This is associated with hypertrophy of the muscle and increase in the connective tissue between the bundles, representing an attempt to overcome the obstruction. Later the overdistended pelvis becomes inert and incapable of efficient contraction on stimulation. It is during the earlier phase that one may hope for success in conservation, though a suitable operation including partial resection of a 'baggy' pelvis may be worth trying in grosser cases.

Secondly, there are the changes in the renal parenchyma resulting from back-pressure. When the parenchyma is grossly thinned the kidney is unlikely to continue as an efficient excretory organ. As such kidneys are usually found to secrete a copious dilute urine, it is difficult to see why the condition should of itself lessen the chances of successful relief of mechanical obstruction. In fact, as Higgins and others (1951) point out, a smooth soft kidney may be no bar to success. The kidney which shows many scars of pyelonephritic change is, however, unlikely to respond to conservation, and possibly the generally concomitant fibrous infiltration of the wall of the pelvis is the determining factor.

Table VII.—Control of Infection after Conservative Operation

	Infected	*Conservation attempted*	*Sterilized after operation*
Group I (Vessels)	9	7	6
Group II (Stenosis)	11	5	3
Group III (Fixation)	11	8	5*

* In 2 of these hydronephrosis is progressing.

Urinary infection does not necessarily jeopardize recovery of function. Of 31 infected cases in the three groups, 14 were sterilized after conservative operation (*Table VII*).

Neither has complicating calculus formation precluded a good result. There were 8 such cases, of which 5 were also infected. Conservation was attempted in 7 and has been successful in 6, with no recurrence of calculi.

AETIOLOGY AND THE ROLE OF THE VESSELS

The Cause of the Dilatation in the Vessel Group.—In many of these cases the position of the vessel, though obstructive at operation, suggested

* Two of these patients have already required operation on the other kidney since the series was collected. In each, attacks of pain in the side developed and I.V.P. showed a moderate degree of hydronephrosis.

In one a Foley Y-V plastic was performed. This procedure is now being used in fixation cases whether or not there is an organic stenosis, in the hope of improving the results in this group. It is too early to assess these cases.

The other case is the one illustrated in *Fig.* 706. An aberrant vessel was also found on the second side with fixation of the junction. Division of the vessel and adhesiolysis was recently performed.

that had the pelvis been undilated the junction region would have remained free from pressure. This is in keeping with Winsbury White's (1925) proposition that the vessel acts as a secondary obstructing factor.

In 15 of the 19 cases fully explored at conservative operation an anomaly of the pelvi-ureteric junction was also described, and in 3 there was some evidence of obstruction lower in the urinary tract. (In those undergoing primary nephrectomy the description was not so complete.) At the upper end of the ureter the pathology included intrinsic stenosis in only 2 cases. In all 15 there was some extrinsic abnormality. In 10 this consisted of 'adherence' of the ureter to the pelvis and in 5 there was kinking caused by 'bands'. These are the same appearances as have been described in the cases unassociated with aberrant vessels, and the successes following their division demonstrates their ability to obstruct the urinary outflow even though the lumen is not intrinsically narrowed.

These 'adhesions' have often been attributed to past inflammation causing peri-ureteritis. Evidence of such an inflammatory origin is not convincing. They are very constantly localized for the results of spread of a diffuse pyelitic process, and histological examination of the region has not supported an inflammatory origin (Östling, 1942). They are found as commonly in early and uninfected cases as in late and infected ones, and in a few the ureter runs within the muscle layers of the pelvis. Only 4 of the 16 recorded in this group occurred in infected cases.

Östling's (1942) study of fœtal and older specimens supports the view that they are congenital in origin. They appear to arise in connexion with the growth of the adventitial coat. In *Fig.* 705 reproductions of some of our operative sketches are shown. Sketch A represents a typical adhesion from the lateral side of the upper end of the ureter to the pelvis. This is Östling's 'sail-shaped fold'. When the pelvis expands during diuresis or from other causes the ureter is dragged up against the pelvis, kinking it. Östling shows photographs of this mechanism in a dissected specimen. The dilatation resulting from this obstruction, and the consequent rotation of the pelvis forward over the psoas muscle, would then cause a secondary obstruction over any vessel which may be present.

It is suggested that the vessel was a secondary factor in these cases. In those in which adhesions were not specifically mentioned a minor degree of fixation may have been present and have been dealt with in the process of 'freeing' the kidney.

The possible occurrence of a vessel so situated that it might cause a primary obstruction during the degree of distension which occurs during normal diuresis is not, of course, thought to be excluded. Our series does suggest that this type must be less common, and we have no case in which such a primary role can be confidently upheld.

On the other hand, it could be suggested that the changes at the junction were the sole cause of the hydronephrosis and that the vessels were not significant. One can only say that the vessels did appear to be causing obstruction and that in 4 cases their division alone caused prompt emptying of the pelvis. Also the results of conservation in the vessel cases have been so very much better than the others as to suggest that they form a genuine group. Furthermore they have seemed to form a group clinically distinct by reason of the more common occurrence of the 'typical' course of hydronephrosis with recurrent attacks of severe renal pain.

These operative and clinical findings are both confirmed in the review by Hellström and others (1949) of 100 mainly adult cases from the Caroline Hospital, Stockholm.

Quinby (1927) has long taught that the vessel obstruction is primary. He states that the pelvi-ureteric junction is normal. This opinion appears to be based on gross and histological examination of the junction after its excision in his operation of reimplantation of the ureter at a site away from the vessel. Extrinsic folds may have been dismissed in clearing the junction. I do not think that an adequately patent lumen should be taken as meaning the absence of obstruction.

Quinby (1929) also suggests that the obstruction may not be simply mechanical, but that the persistent irritation of the arterial pulsation may interfere with peristalsis. He describes experiments in which irritation of the ureter prevented the passage of peristaltic waves. But obstruction by veins alone has been described (one case in this series), and the normal proximity of the gonadal and iliac vessels does not appear to incommode the ureter. Reports of patients with obstruction at the crossing of the uterine artery such as that of Meredith Campbell (1933) stress the coexistence of connective-tissue bands requiring dissection from the ureter.

Foley (1937) has found coexisting obstruction at the pelvi-ureteric junction, and believes that pressure atrophy may cause stricture as a result of the presence of the vessel. In 1937 he described 10 cases of vessel section associated with his Y-plasty on the junction (and nephropexy in 2). He had 7 good results and 1 death.

Deming (1943), reporting his series, believed that the vessels played a secondary role. He believed ptosis of the kidney to be important in causing the ureter to become stretched across the vessel. He performed nephropexy as part of his conservative operations. In this series there is no record of the mobility and position of the kidneys and this factor cannot be assessed.

Meredith Campbell (1933) lists adherence of the ureter to the pelvis, stenosis, and ptosis as primary factors liable to bring a secondary vascular obstruction into play.

Riches (1939), reporting 6 successful cases, considered the role of the vessels to be debatable.

David M. Davis (1947) considered that "all careful studies show that there is usually a ureteral narrowing in addition to aberrant vessels". He advised division of extrinsic vessels and bands and exploration of the ureter.

Hamilton Stewart (1947) considered the vessels to be the major factor and that associated stenosis "must be rare". In his description of his operation, however, he says that after "the pelvis and ureter have been dissected free from the lower polar vessels (artery and vein), and any minute vessels or adhesions maintaining the kink (whether situated in

the ureter or at the ureteropelvic junction or in the pelvis) have been divided, the distension of the pelvis and kidney can be relieved". His follow-up and pyelograms testify to the value of this ingeniously simple and safe procedure.

W. Adams (1951), reporting a series treated in this manner, again stresses the clearing of the junction.

These examples from a voluminous literature show that opinion is divided. *Our series supports the view expressed by Winsbury White that blood-vessel obstruction is a complication not a cause of hydronephrosis, at least in the majority of cases.*

By producing intermittent attacks of acute and painful dilatation the hydronephrosis appears to have been presented clinically before the underlying chronic obstruction had damaged the kidney as severely as in the other cases. (Cf. the more serious effects of insidious chronic retention than those of the more painful acute retention in the urinary bladder.)

We have no evidence to put forward for or against the 'dynamic' factor in hydronephrosis, though we have felt that an organic cause can usually be found by diligent search. Nevertheless the clinical and experimental work of Underwood (1939) and others must be considered. The fixation of the junction has been here regarded as the usual primary factor in hydronephrosis without organic stenosis. The pelvic distension which brings into play its undoubted kinking action has been presumed to be that of normal diuresis (and Östling believes that an early fœtal overgrowth may occur). However, the possibility of an underlying neurogenic lesion has not been excluded and the fixation may in some cases more correctly be considered as a complicating factor like the vessels.

The recent work of Swenson, Macmahon, Jaques, and Campbell (1952) on megalo-ureter is here of interest. They claim to have found a diminution in the parasympathetic ganglion cells supplying the bladder analogous to the changes in Hirschsprung's disease, although the histological picture is not so clear cut.

A similar pathology may underly certain forms of primary hydronephrosis, although the anatomical picture would not be similar as the ganglion cells are not normally present throughout the wall of the ureter. Underwood (1939) made the point that he thought the lesion more likely to be a parasympathetic deficiency rather than an over-active sympathetic, so that peri-arterial neurectomy may not be adequate treatment. He thought that splanchnicectomy may be preferable, so as to leave intact what parasympathetic nerves there were and thus improve the autonomic balance. This would still be a destructive operation and the unsatisfactory long-term results of analogous treatment of Hirschsprung's disease by sympathectomy should be borne in mind.

CONCLUSIONS

1. An organic cause of obstruction was found in 69 of an unselected series of 78 hydronephroses.

2. Renal vessels appeared to contribute to the obstruction in 25 cases.

3. The vessels were considered to act as secondary obstructing factors at least in the majority of cases.

4. Their influence was nevertheless important and so altered the natural history of the disease that a presenting symptom of attacks of renal pain was considerably commoner than in other cases, and a much larger proportion reached the surgeon with a conservable kidney.

5. Conservative operation is a safe and useful procedure in many cases of hydronephrosis in children. Approximately one-third of all these patients have retained a useful kidney. The chances of successful conservation are doubled when an obstructing vessel is present.

6. As a result of attempting conservation a group is left of patients who have obtained symptomatic relief but have a persisting hydronephrosis. Post-operative pyelography is essential in order that this group may be recognized and surveillance and secondary nephrectomy carried out as required. There has as yet been no evidence of hypertension developing in this group.

I wish to thank the members of the staff who allowed me to study their cases, especially Mr. T. Twistington Higgins, under whose care the great majority came, and whose advice and interest have been invaluable. Also the Department of Radiology for their co-operation in the radiological follow-up, and Mr. Derek Martin for his excellent photography. Finally I would like to thank Mr. Douglas Stephens for his original suggestion of this study.

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EXPERIMENTAL SURGERY

THE EFFECTS OF LIGATION OF THE PELVIC ARTERIES ON THE VIABILITY OF THE URINARY BLADDER AND THE SUFFICIENCY OF THE COLLATERAL CIRCULATION IN THE EXPERIMENTAL ANIMAL

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DURING the past decade the scope of arterial ligation in pelvic surgery has increased considerably. Thus bilateral ligation of the internal iliac arteries as recommended by Leventhal, Lash, and Grossman (1938), Franco and Nery (1940), and Brunschwig (1951), is now practised by an increasing number of surgeons, either as palliative treatment or during radical extirpation of pelvic carcinomata. Franco and Nery (1940) have also recommended the procedure for benign hypertrophy of the prostate gland. Although ensuing complications are few, they do occur; Finaly (1925), for instance, reported necrosis of the bladder following bilateral ligation of the internal iliac artery.

In spite of the advances in pelvic surgery, very little experimental data are available concerning the effects on the pelvic viscera, particularly the urinary bladder. A comprehensive study has therefore been undertaken of the gross and microscopic changes in the urinary bladder following ligation of individual pelvic arteries and combinations of these; since the morphology of the collateral circulation is intimately concerned with this problem, an investigation of the detailed collateral arterial channels was made concurrently.

Rodents, Lagomorpha, and Primates are the only mammals in which the aorta divides into two common iliac arteries which terminate in external and internal iliac branches (Young, 1891; Parsons, 1902); furthermore, there is also a similarity in the arterial supply to the bladder in these animals and man. The arterial supply to the bladder in man has been described previously in some detail (Braithwaite, 1952, a).

In view of the large numbers of animals required for this investigation, the rabbit (Lagomorph) and rat (Rodent) were used, because of their ready availability and comparatively low cost.

MATERIALS AND METHODS

The anatomy of the pelvic arteries was studied in 12 unoperated animals (6 rabbits and 6 rats), additional observations being made on all operated animals at the time of sacrifice.

Operative procedures were successfully undertaken in 88 animals (32 rabbits and 56 rats), the type of operation varying from occlusion of a single vesical artery to bilateral interruption of the common iliac arteries. The rabbit series with a weight range of 1·8 to 2·7 kilos consisting of animals of both sexes was subjected to the procedures listed in *Table I*. The rat series, predominantly female, consisted of animals whose weights ranged between 147 and 215 g. *Table II* indicates the nature of the operations performed.

Operative Technique.—The anæsthetic used for the rabbit was Veterinary Nembutal (Abbott Laboratories), whereas open ether was employed in the case of the rat. The operative technique was similar in both series.

Table I.—OPERATIONS ON THE RABBIT

Unilateral ligation :—	
Superior vesical artery	4
Umbilical artery	4
Common iliac artery	8
Bilateral ligation :—	
Superior vesical arteries	4
Umbilical arteries	4
Internal iliac arteries	4
Common iliac artery of one side and of the contralateral umbilical and internal iliac arteries	4
	32

A midline incision about 2 in. in length provides adequate exposure of the division of the abdominal aorta, the common iliac arteries, and the pelvic viscera. The common iliac vessels were dissected in a proximo-distal direction, thus enabling the external, internal, and umbilical arteries to be identified at their origins. The vessels were either divided or occluded by double-thread ligatures, the effectiveness of the procedure being later confirmed by the injection of a radio-opaque medium. The survival period varied between twenty-four hours and three months, those with bilateral ligations being allowed to survive for longer periods. On sacrifice, the animals were injected slowly with a suspension of 10 per cent bismuth oxychloride (" Chlorbismol ") through either the abdominal aorta distal to the origin of the renal arteries (rabbit), or via the thoracic aorta (rat), using pressures below the usual height

Table II.—OPERATIONS ON THE RAT

Unilateral Ligation :—	
Superior vesical artery	5
Umbilical artery	5
Internal iliac artery	3
Umbilical and internal iliac artery	3
Common iliac artery	7
Bilateral ligation :—	
Superior vesical arteries	8
Umbilical artery	5
Internal iliac artery	3
Umbilical and 1 internal iliac artery	3
Umbilical and 2 internal iliac arteries	3
Common iliac arteries	8
Common iliac and uterine arteries	3
	56

of blood-pressure. This technique filled the pelvic vessels uniformly. Radiological and dissection methods were used for the study of the morphology of the collateral circulation. The bladder was later removed and its macroscopical appearance noted.

Histological studies were confined to the rat bladder only, because of its comparatively small size and thicker muscular wall (the rabbit bladder is extremely thin-walled, with a poorly developed muscle coat). Sections cut 1 in 10 and stained with hæmatoxylin and eosin were compared with material

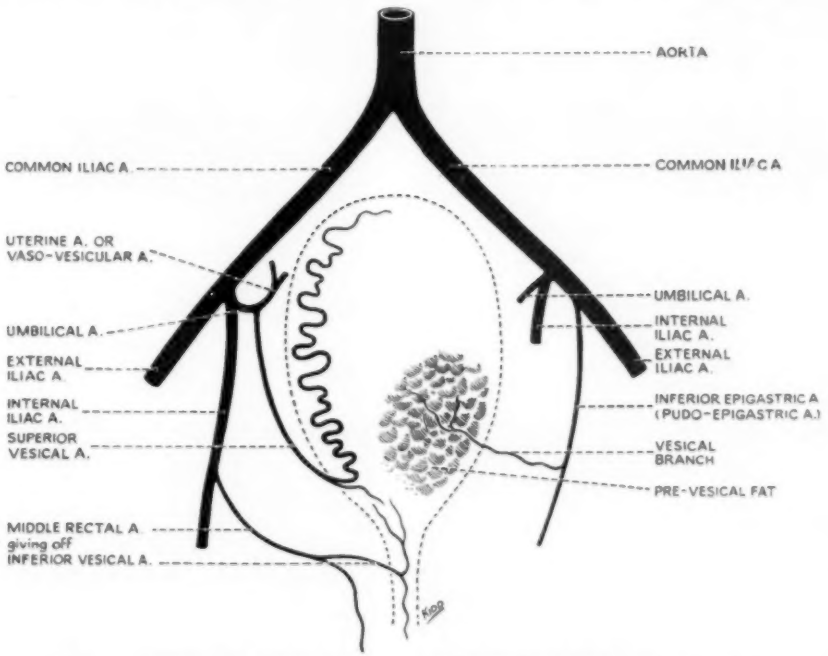


FIG. 710.—Diagram of the arteries of the urinary bladder in the rabbit and rat.

treated similarly from control animals. Some specimens were also subjected to the Pickworth (1934) technique for the assessment of the nature of the capillary bed.

ANATOMY OF THE PELVIC ARTERIES

All mammalia show some variation in the origin of the pelvic arteries from their parent trunks, particularly the parietal branches. This aspect has been discussed previously in some detail with reference to man (Braithwaite, 1952, b). The visceral pelvic arteries concerned with the supply of the bladder are, however, with the exception of the inferior vesical artery, more constant in origin. The following description embraces the most frequent origins of the vesical arteries in the rabbit and rat.

The urinary bladder in these animals is supplied from two main sources, the umbilical artery and internal iliac artery. Some small contributions also run to the prevesical fat from the inferior epigastric (pudo-epigastric) artery (*Fig.* 710).

1. **Umbilical Artery.**—The origin of this vessel differs from that in man by arising from the trifurcation of the common iliac or alternatively from the proximal part of the internal iliac artery. It gives off the superior vesical artery or arteries, which form by far the most important source of arterial supply to the bladder in both sexes. The uterine artery also arises from the umbilical in the female, whilst in the male the vasal (to ductus deferens) and vesicular (to seminal vesicle) branches are given off, either separately or from a common trunk; small contributions from these sources supply the posterior aspect of the bladder and the terminal ureter.

2. **Internal Iliac Artery.**—The vesical contributions from this source come from a vessel arising in common with the middle rectal artery. A small contribution is given to the bladder neck and urethra.

3. **External Iliac Artery.**—The inferior epigastric artery (' pudo-epigastric ' artery in the rat) is given off prior to the parent vessel running deep to the inguinal ligament, and branches from these sources can be traced to the anterior aspect of the bladder, terminating mainly in the prevesical fat although some can be followed to the bladder wall itself.

FINDINGS

The findings in these experiments will be discussed under two headings: (1) The effects of ligation of the vesical arteries; (2) The effects of ligation of more remote pelvic vessels.

1. The Effects of Ligation of the Vesical Arteries.—

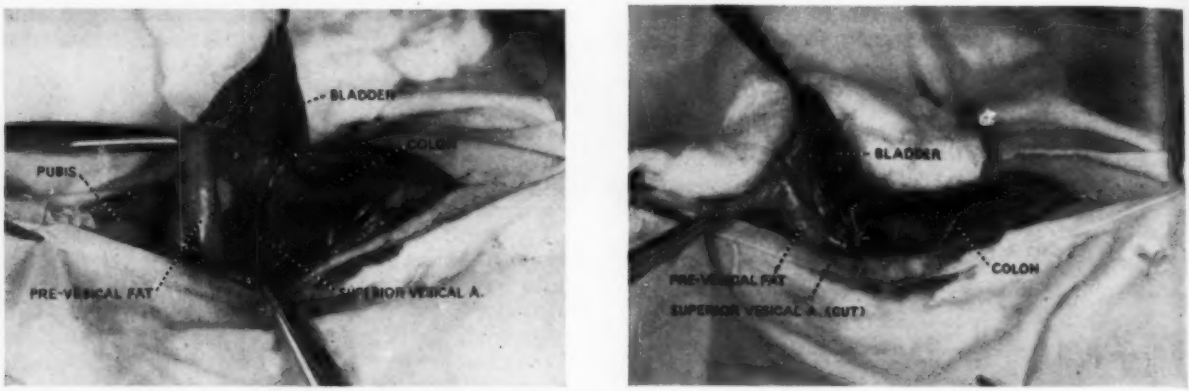
a. Unilateral Ligation of Superior Vesical Artery.—In these experiments the collateral circulation was sufficient to prevent any threat to the viability of the urinary bladder.

Fig. 711 illustrates the left superior vesical artery in a rabbit *before* and *after* division. Prior to section the collateral branches radiating from the main stem are seen clearly as well-marked transverse channels. After division the bladder has contracted and appears avascular, and only slight traces of the inferior branches of the superior vesical artery are observed. After occlusion of the artery an increased pulsation

becomes evident almost immediately in the contralateral superior vesical artery, its transverse branches become enlarged and more tortuous as the compensatory collateral mechanism from this source opens up. This response was well-marked in all animals.

Fig. 712 illustrates the comparative sizes of the superior vesical pedicles in a rabbit in which unilateral division of one of these had been carried out

Concomitant peritonitis was evident and a foul-smelling seropurulent exudate was present. The tissue was subjected to the Pickworth (1934) technique to study the state of the capillary bed (*Fig.* 713 A). The collateral circulation, which is dependent initially on the anastomosis between vessels of capillary size, was in this instance totally inadequate; this is evident when compared with a capillary bed



A B

FIG. 711.—The left superior vesical artery and its branches: A, before division; B, after division. In B the bladder has contracted and only slight traces of the inferior branches of the superior vesical artery are seen.

A B

FIG. 712.—Comparison of the superior vesical arteries and their branches. A, The right superior vesical artery was divided a week before sacrifice. B, The left superior vesical artery has become more tortuous to compensate for the ligated vessel.

a week before sacrifice. The undivided vessel has become increasingly tortuous to compensate for the occlusion of the contralateral vessel.

The histological appearances of the bladders in all of these animals were within normal limits.

b. Bilateral Ligation of the Superior Vesical Arteries.—The effects of this operation were observed in 12 animals (4 rabbits and 8 rats), the period of survival varying between twenty-four hours and three months. It was in this group that the maximum effect on the bladder was manifested.

Following operation the bladder lost its normal transparency and became a dusky purple. Hot swabs were applied to its surface before returning it to the abdomen. Three deaths occurred (2 rabbits, 1 rat) within forty-eight hours. On post-mortem examination of these animals the bladder was found to be gangrenous. In one of these, two small areas in the superior wall had sloughed in addition. which had become opened up during a similar operative procedure (*Fig.* 713 B).

Nine animals recovered and 4 of these were dissected to observe which of the preformed anastomoses had become secondarily enlarged to establish an adequate circulation. In the male animals the observed anastomoses occurred between :—

i. The inferior vesical (branch of the middle rectal) and the superior vesical arteries.

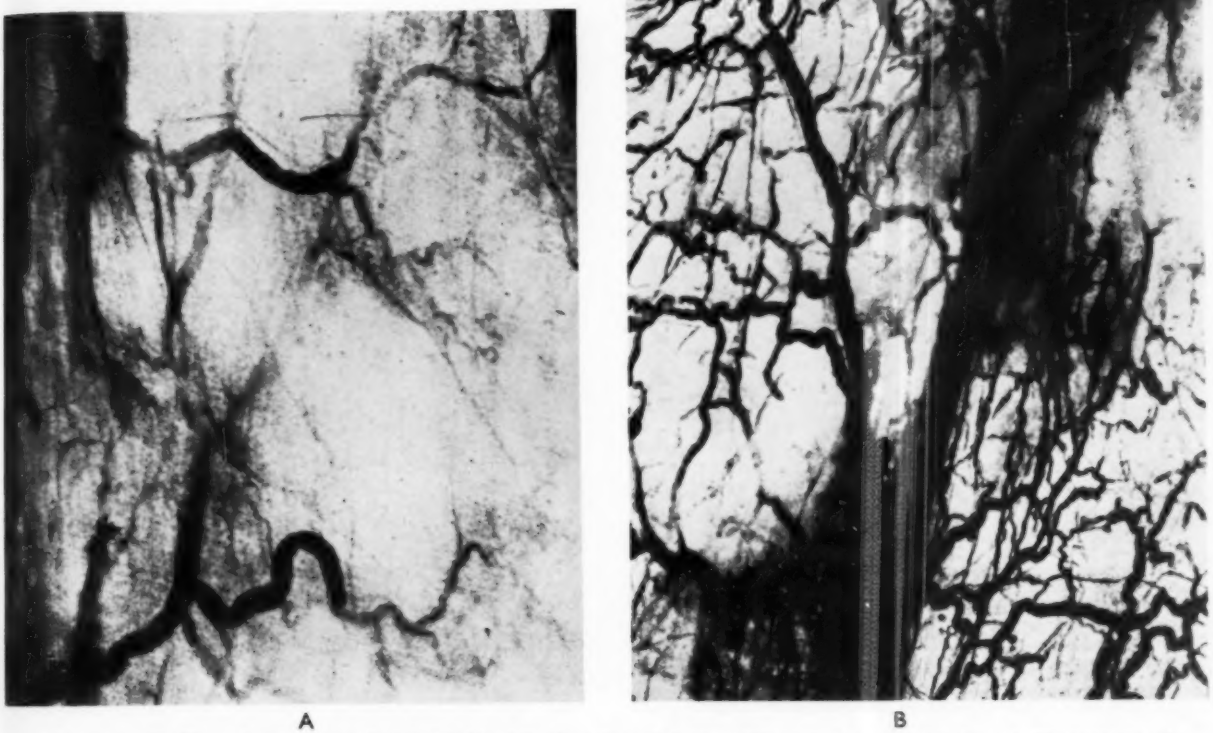
ii. Prevesical branches of the deep epigastric and the superior vesical arteries.

iii. Vessels running along the ureteric sheath and ureteric branches of the vesical arteries.

In the female animals similar anastomotic channels between the vesical arteries were evident, with anastomoses between the uterine and vesical arteries forming additional collateral channels.

Histological Appearances.—The bladder, although apparently normal on naked-eye appearance in

all the animals recovering from operation, nevertheless showed distinctive histological changes after bilateral ligation of the superior vesical arteries. The presence of the heterozoan worm, *Trichosomoides crassicauda*, a normal inhabitant of the rat bladder, was not considered to be responsible for the changes observed, since these nematodes were present in similar numbers and phases of development in both the control animals and in those that had undergone operative procedures other than bilateral ligation of the superior vesical arteries.



A B

FIG. 713.—Capillary plexus in the wall of the bladder following bilateral ligation of the superior vesical arteries. A, The appearance in the necrosed bladder. B, The appearance in an animal surviving the operation. In A the capillary bed has not become opened up. Pickworth method. (× 90.)

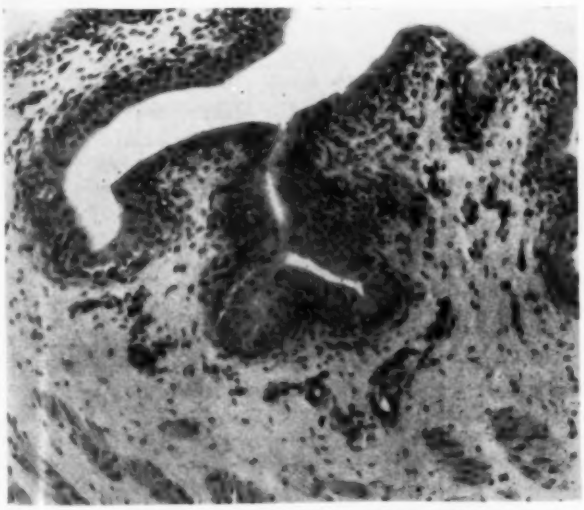


FIG. 714.—T.S. Control bladder. Note the normal appearance of the epithelium. H. and E. (× 105.)

The normal appearance of the rat bladder is shown for comparison in *Fig.* 714. The first change to be noted occurs three days after operation and consists of slight shedding of the more superficial parts of the epithelium (*Fig.* 715). This is a progressive change which reaches a maximum between ten and fourteen days after operation.

FIG. 715.—T.S. Bladder three days after the operation of bilateral division of the superior vesical arteries. Note the shedding of epithelium. Many of the cells are vacuolated and their nuclei pyknotic. H. and E. (× 105.)

Fig. 716 shows a typical appearance in an animal that had survived fourteen days, in which all except the basal layer of cells of the epithelium has been shed to form a large amorphous mass in the bladder lumen. This epithelial separation is uniform throughout the bladder, although slightly more pronounced near the superior aspect of the organ.

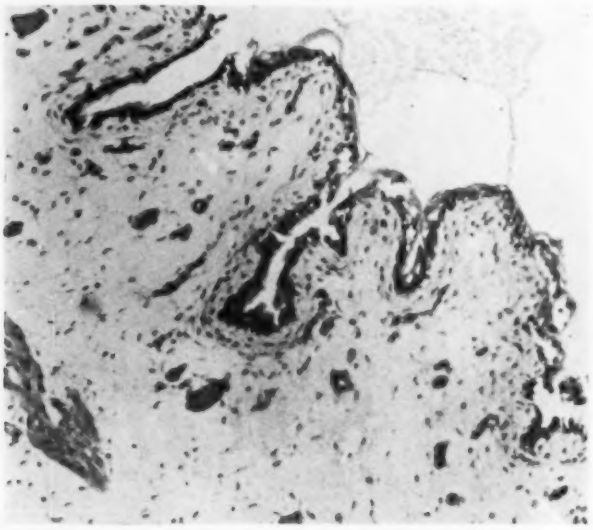


FIG. 716.—T.S. Bladder fourteen days after the operation of bilateral division of the superior vesical arteries. Most of the epithelium has separated, only the basal cells remaining. H. and E. (× 105.)

In the majority of specimens there was also evidence of atrophic change in the smooth muscle of the bladder.

Regeneration of the epithelium does eventually occur, as can be seen in material examined three months after operation, when the histological appearances have returned to within normal limits.

2. The Effects of Ligation of More Remote Pelvic Arteries.—Since detailed accounts of the results of all operations would involve a great deal of space for both description and illustrations, only certain examples of the operative results in Group 2 will be described.

In the 67 experiments covering a wide variety of ligations, no gross changes were apparent in the urinary bladder; in 2 experiments only (bilateral ligation of the umbilical arteries) did the histological appearances of the epithelium differ from normal.

Unilateral Experiments.—

a. Ligation of the umbilical artery: The anatomical relationships in this procedure differ from those in ligation of the superior vesical artery by preserving the indirect communication between the spermatic (ovarian or testicular arteries) and vesical vessels through the utero-ovarian and vaso-testicular anastomoses. Nine operations of this type were undertaken, and it was evident in all that enlargement of the ipsilateral spermatic anastomosis formed the most conspicuous feature.

b. Ligation of the common iliac artery: This procedure, carried out in 15 animals (8 rabbits and 7 rats), was better tolerated by the rat. The degree of impairment of the use of the hind limb was greater in the rabbit, and full function did not return in some cases until three weeks after operation, whereas in the rat the ensuing complications had resolved after three to four days. The nature of the collateral channels was, however, similar in both animals.

Fig. 717 shows the appearance following division of the left common iliac artery in an animal sacrificed after three days, at which stage there is no evidence

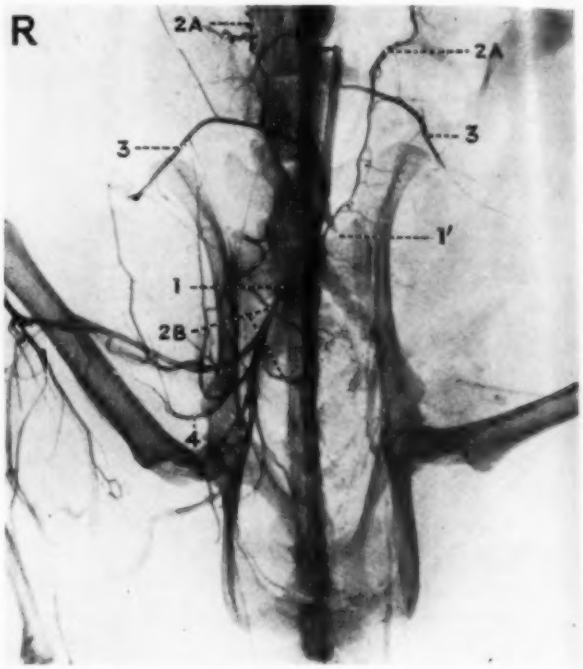


FIG. 717.—Arteriogram following division of the left common iliac artery. The animal was sacrificed three days after operation. There is no evidence of enlargement of the collateral channels of macroscopical size.

1, Common iliac artery, 1', Common iliac artery (cut), 2, Utero-ovarian anastomosis, 2A, Ovarian artery, 2B, Uterine artery, 3, Iliolumbar artery, 4, Deep circumflex iliac artery.

of a compensatory mechanism by means of the macroscopic channels. *Fig.* 718, a week after operation, demonstrates the establishment of the collateral circulation by means of vessels of arterial size. The enlargement of the utero-ovarian anastomosis is particularly evident; a network of smaller vessels has also opened up between the iliolumbar branch of the aorta and deep circumflex iliac branch of the external iliac artery.

Bilateral Experiments.—

c. Bilateral ligation of the umbilical arteries: This procedure was undertaken in 9 animals (4 rabbits and 5 rats). In 2 of the latter, sacrificed respectively at ten and fourteen days after operation, the degree of epithelial shedding exceeded the normal. The channels which had undergone enlargement in the remainder consisted of the spermatic anastomosis, the iliolumbar-deep-circumflex-iliac, and the vesical and ureteric anastomoses.

d. Bilateral ligation of the internal iliac arteries: This operation was undertaken in 7 animals (4 rabbits and 3 rats) and also revealed no effect on the viability of the bladder. The major anastomotic channels offering alternative routes were between the parietal branches of the internal iliac artery and branches of the external iliac (these have previously

been described in detail by Olovson, 1941). The spermatic and caudal anastomoses (between lateral caudal branches of internal iliac and median caudal from the aorta) also underwent enlargement.

e. Bilateral ligation of the common iliac arteries: This and other more major procedures have been carried out exclusively in the rat, 8 operations having been successfully undertaken. This animal withstands the procedure well, the impairment of movement of the hind limbs being only temporary, recovery occurring within four days.

FIG. 718.—Arteriogram following division of the right common iliac artery. The animal was sacrificed a week after operation. Note the enlargement of the right utero-ovarian anastomosis and the network of smaller vessels along the course of the right iliolumbar artery. Key as in *Fig.* 717.

Fig. 719 shows the degree of enlargement of the collateral channels after two months, when compensation has become fully established, the utero-ovarian and iliolumbar-deep-circumflex-iliac anastomoses, particularly those on the left side, having undergone considerable enlargement.

DISCUSSION

It is evident from these experiments that, except where the two main vascular pedicles of the bladder (i.e., the superior vesical arteries) are ligated, it is not possible to impair the viability of the bladder in the experimental animal (rabbit and rat).

The results of interruption of arteries supplying the bladder obviously depends upon the efficiency of the collateral circulation. In the 3 instances in which animals died as a result of operative interference the bladder circulation was inadequate, and the anastomoses between the occluded superior vesical arteries and the other sources of vesical supply (inferior vesical; deep epigastric) were unable to compensate for the interruption of the more important channels.

In the animals recovering from bilateral interruption of the superior vesical arteries, the collateral circulation was sufficient to prevent necrosis of the bladder, although insufficient to prevent changes, observed histologically, mainly affecting the epithelium and, though to a lesser degree, the smooth muscle. The maximal effect is on the epithelium,

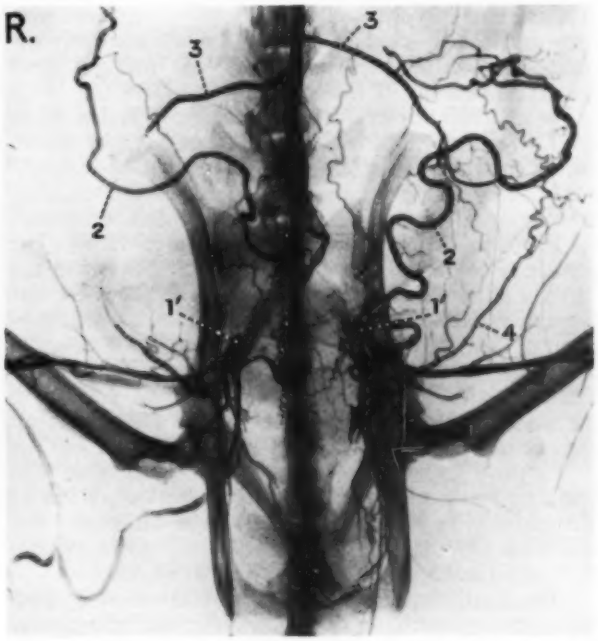


FIG. 719.—Arteriogram following division of both common iliac arteries. The animal was sacrificed two months after operation. Note the compensatory enlargement of the preformed macroscopical channels. Key as in *Fig.* 717.

presumably because this tissue is farthest removed from the source of arterial blood. The efficiency of the local circulation gradually increases in time, so that the epithelium returns to within normal limits.

The ligation of more remote pelvic arteries produced negative results with the exception of 2 cases of bilateral section of the umbilical artery, in which the degree of epithelial shedding exceeded normal limits.

It will be appreciated that the further the ligated vessel is from the bladder, the greater will be the number of intervening anastomotic channels capable of contributing to the maintenance of the collateral circulation, a factor which has an important bearing on these negative results.

Following interruption of an artery or arteries of supply to a tissue, Offergeld (1907) and Olovson (1941) have shown that anastomoses of capillary dimension are more important than preformed macroscopical channels in the establishment of a collateral circulation. This has been mainly confirmed in this investigation, although where a large arterial channel anastomoses with the occluded vessel distal to the site of occlusion the changes within the tissue are less severe than when the vessel is interrupted distal to the site of this anastomosis. There is a latent period before the preformed macroscopical anastomoses become noticeably enlarged. Olovson (1941) found this period to be

approximately a week in the rabbit, and the present observations confirm this. The latent period in the rat of approximately four days is somewhat shorter.

The pattern of the collateral circulation varies not only with the length of survival period after operation, but obviously with the vessel or vessels ligated. The size of the artery interrupted bears a direct relationship to the degree of enlargement of the vessels in the collateral circuit; in this series the maximum change follows occlusion of the common iliac arteries and was least marked after unilateral section of the superior vesical artery.

In general, however, the most noticeable dilatation following the more extensive bilateral procedures occurs in the spermatic and iliolumbar-deep-circumflex-iliac anastomoses and often there is also enlargement of the ureteric and mesenteric anastomoses.

From this study it does appear that in view of the similarity of pelvic arterial arrangements between the experimental animals and man there is some experimental rationale for such procedures as bilateral interruption of the internal iliac artery in selected cases in man. Obviously the capacity of the collateral circulation to open up will be related to the state of the vascular tree—itself dependent on the age and general condition of the subject.

Caution must be expressed in ligation of the important vesical arteries (superior vesical) close to the bladder as this procedure would eliminate the collateral channels between these and other vessels and may endanger the viability of the viscus.

The significance of the results obtained in ligating the common iliac arteries will be described elsewhere. It is outside the scope of this paper, as it entails detailed descriptions of the collateral circulation to the lower limbs; suffice it to say here that the procedure does not involve any danger to the viability of the bladder.

CONCLUSIONS AND SUMMARY

1. The normal arterial supply to the urinary bladder has been studied in the rabbit and rat.

2. Ligation experiments of individual pelvic arteries and combinations of these have been carried out on 88 animals, ranging from interruption of a single vesical artery to occlusion of both common iliac vessels.

3. Following the operation of bilateral division of the superior vesical arteries, the effect on the bladder varies from increased shedding of the epithelium and atrophy of the smooth muscle coat to necrosis of the wall (in 3 out of 12 experiments), the former being the result of temporary ischæmia.

4. Ligation of more remote arteries produces no threat to the viability of the bladder because of the adequacy of the collateral circulation.

5. The bearing of these results on similar procedures in man is discussed. It is suggested that these experiments provide an experimental rationale for such procedures as bilateral ligation of the internal iliac artery in selected cases in man.

My thanks are due to Professor R. G. Harrison for the benefit of his experience and valuable advice during the major part of this work; to Professor G. A. G. Mitchell for allowing me all facilities in his Department during the earlier part of this work. I am also indebted to Messrs. P. Howarth (*Figs.* 711–713) and L. Cooper (*Figs.* 714–719) for the photography, Miss B. Birkett for the histological preparations, and Mr. D. Kidd for the illustrations.

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EXPERIMENTAL CARDIOVASCULAR SURGERY *

FURTHER EXPERIMENTS ON THE AZYGOS FACTOR

BY A. T. ANDREASEN AND F. WATSON

THIS paper reports further results in continuation of work already published (Andreasen and Watson, 1952) on the significance of the azygos factor in survival during caval occlusion, and is concerned with a study of the effect of varying sizes of flow artificially introduced through the azygos vein under the same conditions.

In order to confirm that it was actually the azygos flow and not some other factor which had maintained life in our series of experiments it was necessary, in the first place, to show that an artificial flow, of the same size as the natural one, would maintain life equally well. To study the effect of larger flows under the same conditions was but an extension of the same work. Other points, now reported, concern smaller technical arrangements at first kept constant throughout, the significance of which later became important for a fuller interpretation of the results obtained.

* This work, and that reported in the preceding publication on the Azygos Factor, was carried out during the tenure of the Leverhulme Research Scholarship at the Royal College of Surgeons of England.

TECHNIQUE

The standard azygos preparation of the earlier work was used throughout, with the addition of exposure of the femoral vein in the groin, and isolation of a length of azygos sufficient to permit easy cannulation. By freeing the azygos from its pleural covering and clearing it as far down as the entrance of the first intercostal tributary, a suitable length can be obtained. The vein is double ligated just above this tributary, severed between these and the heart, and drawn up into the thoracotomy wound by a small Halsted hæmostat. The latter is left in place to balance the vein whilst the cannula is being introduced. The femoral vein is isolated through a vertical incision in the overlying skin, tied off immediately proximal to the entrance of the profunda tributaries, but not divided. To get a good constant venous return the tip of the cannula must lie just inside the inferior vena cava, that is, about 15 cm. up from the entrance of the cannula into the vein. To facilitate the passage of the cannula the leg should be straightened before making any attempt at insertion. The cannulæ used were of polythene tubing, 4 mm. in diameter and long enough, in each case, to reach from the vein to the rubber tubing passing through the pump. Blood flowed into the pump from the femoral vein and out through the azygos cannula and vein to the heart. The pump was a small Jouvelet pattern blood transfusion hand-pump which had been converted to a pulley drive from a motor. Each stroke of the Jouvelet delivered approximately 2 c.c., given an adequate, free, venous feed from the femoral. The number of strokes per minute was controlled by using a smaller or larger driving pulley. In this way it was possible to arrange the delivery of any desired flow from 50 c.c. to 300 c.c. per minute at will. The whole system was calibrated by direct measurement and by the electromagnetic flow-meter before, during, and after experiment.

In order to start an experiment, the pump having been adjusted to the desired flow, and the dog accurately heparinized, the system of cannulæ and pump are filled with normal saline to exclude air-bubbles. Next the cannulæ are inserted into their respective veins and secured. The superior vena cava is then clamped off, followed by the inferior cava. Coincident with the clamping of the latter the stop-watch and the pump are started.

It should be mentioned here that it had been found difficult to obtain a venous return flow sufficient to feed the pump when the larger flows were being used, unless the head end of the dog was elevated some 20–30°—a simple manœuvre which increased the flow up to about 300 c.c. per minute—and when the larger flows were in use this position was constantly adopted. Its significance as a variation to the original standard conditions is discussed later.

Another variation, introduced with the idea of obtaining freer return of the venous blood and of relieving the engorgement of the head and neck seen in caval clamping, was the use of a polythene tube between the superior and inferior cavæ. This ' caval shunt ' had already been used in some other experiments, as yet unreported, and we considered that it might be an advantage here, especially with the larger flows. The shunt was of polythene tube, 13 cm. long and 3 mm. in diameter. It was prepared by passing a nylon suture through one end and knotting it in place. Mounted on the drawn-out end of a glass tube of nearly the same diameter, with the nylon suture ends held against this glass tube with the fingers, it was relatively easy to introduce the shunt through the external jugular vein, down the superior cava, and across the right auricle into the inferior cava. The fingers of the operator located the shunt through the walls of the cavæ and controlled its exact position. Then, with the shunt held firmly in position through the thoracotomy wound, the glass tube was detached and withdrawn from the jugular opening. The suture ends were left outside the vein and a bulldog clip was applied just proximal to the opening in the vein. The suture allows quick recovery of the shunt at any time. It was found that there was almost no blood-loss during these manipulations once some practice had been obtained. The shunt, being of narrow tubing, did not come into action until the cavæ were constricted tightly about it by means of a plastic ligature passed around the cavæ. A small rubber cuff was pushed down over the two ends of each ligature to tighten them and by this means closed off the cavæ from the heart. A small hæmostat clipped on the ligature above the rubber cuff kept the pressure constant and avoided accidental slipping. (Andreasen and Watson, 1953.) The method has the advantage of being easily brought into action and is easily released without any damage to the caval walls. The shunt was efficient in all cases.

RESULTS

Table I sets out the results of six experiments in which flows of 80 c.c. to 95 c.c. per minute were introduced during a thirty-minutes' caval occlusion period. There were two deaths. The first of these was accidental and occurred because the polythene tube leading into the azygos slipped from its pump attachment. The blood lost, together with the time taken to refit and re-start the pump, proved to be fatal and the dog died in four to five minutes from the time of the accident.

Table I.—Small Artificial Azygos Flows

Experiment Number	Duration of Flow	S.V.C. I.V.C.	Flow in c.c. per Minute	Result
1	30 min.	Clamps	80	Survived and recovered
2	30 min.	Clamps	95	Survived and recovered
3	30 min.	Clamps	95	Died*
4	30 min.	Clamps	90	Survived and recovered
5	30 min.	Clamps	90	Survived and recovered
6	30 min.	Shunted	90	Died

* Accidental death

The second death occurred in the only dog in the series in which a caval shunt was used. About fourteen minutes from the start of the experiment breathing had ceased; a minute or so later the heart began to fail by fibrillation. Immediate re-establishment of the circulation and massage were ineffective and the dog died.

Fig. 720 is typical of the tracings obtained in this series, the dog in this instance receiving 90 c.c. of blood per minute through the azygos cannula. The blood-pressure drops almost to zero as the caval clamps are closed and the pump started. This is due to the fraction of a second difference between the cutting off of the efficient venous return and the pump reaching full power. The pressure soon rises to 40 mm. Hg, remains at that level throughout the experiment, but shows a slight steady fall totalling only 5–8 mm. Hg by the end of thirty minutes. The recovery on release of the clamps and stopping the pump is as smart and lasting as it was in the original natural azygos flow series. By the end of half an hour the pressure reached the pre-operation level of 125 mm. Hg.

In the second series a flow of approximately twice that used in the first series was aimed at, and the flow nearest to this figure obtainable with the sizes of pulleys available proved to be 216 c.c. per minute; the caval occlusion times were thirty to forty minutes' duration. The results of this set of eight experiments are shown in *Table II.* It was

Table II.—Large Artificial Azygos Flows

Experiment Number	Duration of Flow	S.V.C. I.V.C.	Flow in c.c. per Minute	Result
7	30 min.	Clamps	216	Survived and recovered
8	40 min.	Clamps	216	Survived and recovered
9	40 min.	Shunted	216	Died
10	40 min.	Shunted	216	Died
11	30 min.	Clamps	210	Survived and recovered
12	30 min.	Shunted	216	Died
13	30 min.	Clamps	210	Survived and recovered
14	30 min.	Clamps	210	Survived and recovered

necessary to find out whether the casualty in the first series was due to the introduction of the caval shunt or to some other accident, and in three dogs in the second series, therefore, a caval shunt was used. All three died. In each case breathing stopped between the fourteenth and eighteenth minute. The heart continued to beat strongly for a variable time after this. *Fig.* 721 is the blood-pressure tracing obtained from the case in which survival with the shunt was most prolonged. It illustrates the main features of the shunted cases on the higher flow. The initial drop and rise, coincident with the short-circuit of the heart by the closing of the cavæ around the shunt and the pump coming into action, are very marked. The rise shows up the remarkable effect of raising the flow from 95 c.c. to 216 c.c. per minute —which is still only a fraction of the normal caval return with the chest open and the dog anæsthetized and pinioned on its back. What is more, this higher level of pressure is fairly well maintained throughout the experiment. However, there is a steady drop to the point where breathing becomes irregular and finally stops. The heart is seen to continue beating strongly until the end of the experiment—a further period of eight minutes. Recovery of a blood-pressure of 160 mm. Hg occurs on release of the shunt but breathing did not recommence nor were artificial respiration methods of any avail. Death occurred approximately fifteen minutes after re-establishment of the natural circulation. Correlation of the blood-pressure observations with those made generally and noted through the open chest wall give the clue as to why breathing fails in the shunted cases. The efficiency of the shunt in relieving the congestion of the head and neck is quite obvious. Very soon after it comes into action there is blanching of the tongue and collapse of the superior vena cava to the diameter of the shunt tube. The pupil dilates and the fundus of the eye blanches. By the tenth to the twelfth minute the veins running into the cavæ are practically empty. These effects are observed in the horizontal position as well as with head elevation; they are more marked and come on earlier in the latter. The dog appears to be almost decorticate.

In marked contrast to these three results are the consistent recoveries of the five animals in which simple caval clamping was employed. *Fig.* 722 is a typical example of blood-pressure tracings in this group. The initial drop in pressure is less marked and the general level of pressure during the caval occlusion is higher; there is a constant upward trend as the end of the experiment approaches, until on release of the clamps and stopping the pump there is immediate and uneventful recovery. A further significant difference is the retention of all the reflexes, such as the pupillary, tongue, jaw, and general muscle tonus, in these 'clamped' dogs as opposed to the decline of reflexes observed in those with shunts in operation, and the temporary loss of all reflexes in those with the cavæ clamped but on the smaller flows. Head elevation had no effect upon the clamped dogs, beyond a momentary dip of pressure as the degree of elevation was changed. An experiment was carried out with a table capable of a tilt up to 65°, head up or down. With a dog receiving 216 c.c. per minute, the chest open and the cavæ clamped, there was no significant change in the blood-pressure from the head down by 60° to the head up by the same degree. As each change of 20° was made there was just a small momentary dip which was at once re-adjusted. It was further noted that the optimum position for venous return by gravity was between 20° and 30° head elevation. Further rises above this were without significant effect on the flow from the femoral vein.

DISCUSSION

Taking together the facts observed :—

1. That head elevation is necessary to obtain an adequate venous return, i.e., the venous return is best ensured by gravity;

2. That the dogs in which caval clamping is employed live through the experiment consistently, and those with a caval shunt inserted die equally consistently;

3. That in the latter the head is quickly blanched but without any greater venous return that in the former—it seems clear that once the heart is out of circuit, even when the brain and myocardium are kept alive by the minimum flow provided by the natural azygos, there occurs a large subdiaphragmatic 'pooling' of the available blood. Of course, the disadvantage at which the dog is placed by its

reversed position on the table, by having its chest open for a long period, and by the restricted ventilation consequent, is considerable, but it is not until the heart is short-circuited by one means or another that the full effect is observed. It is not surprising that this 'pooling' should occur when general loss of tone is seen to set in from the time the heart is put out of circulation. Further evidence of this 'pooling' is seen in the fact that, on the flows we employed, the best means of ensuring a fairly constant venous return to the pump is by gravity alone. Attempts to suck out larger quantities of

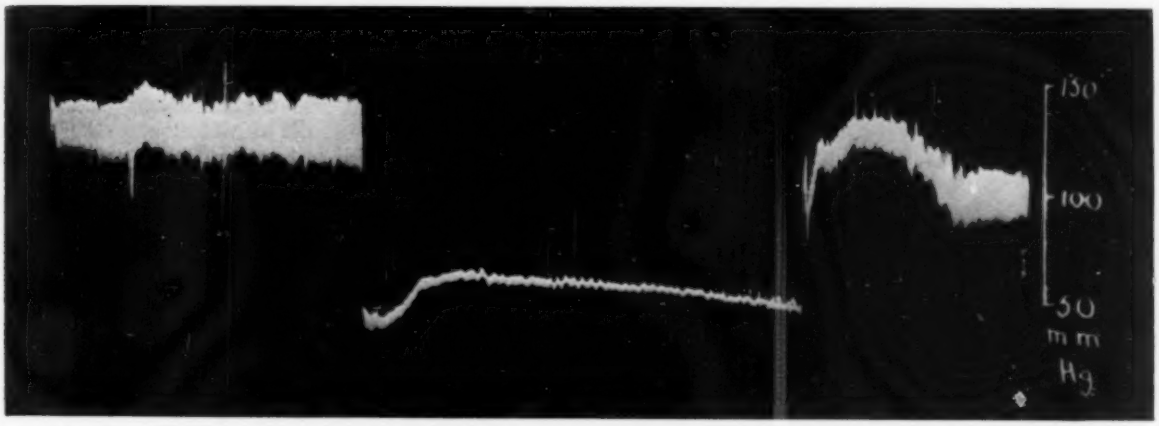

FIG. 720.—Blood-pressure tracing of dog receiving 90 c.c. per minute through the azygos vein, the cavæ clamped off.

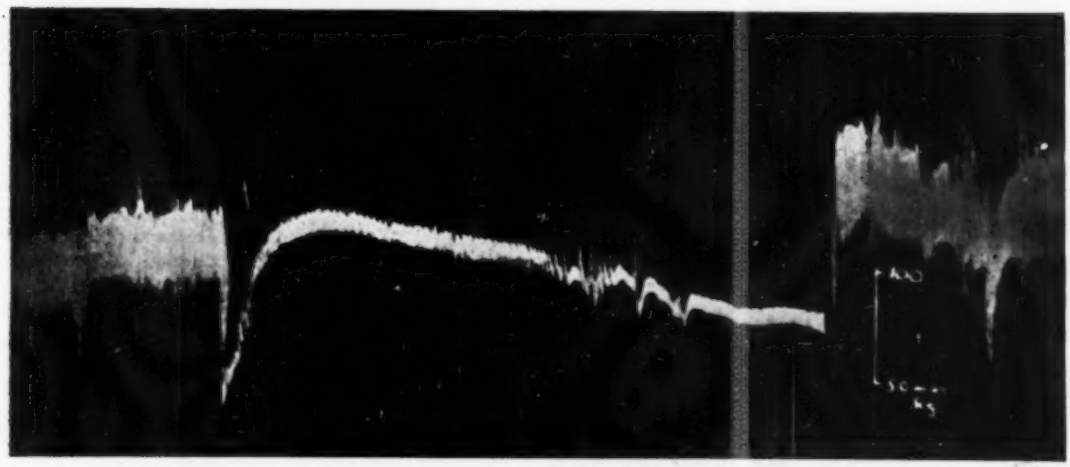

FIG. 721.—Blood-pressure tracing of dog receiving 216 c.c. per minute through the azygos vein, with a shunt from the superior to the inferior vena cavæ.

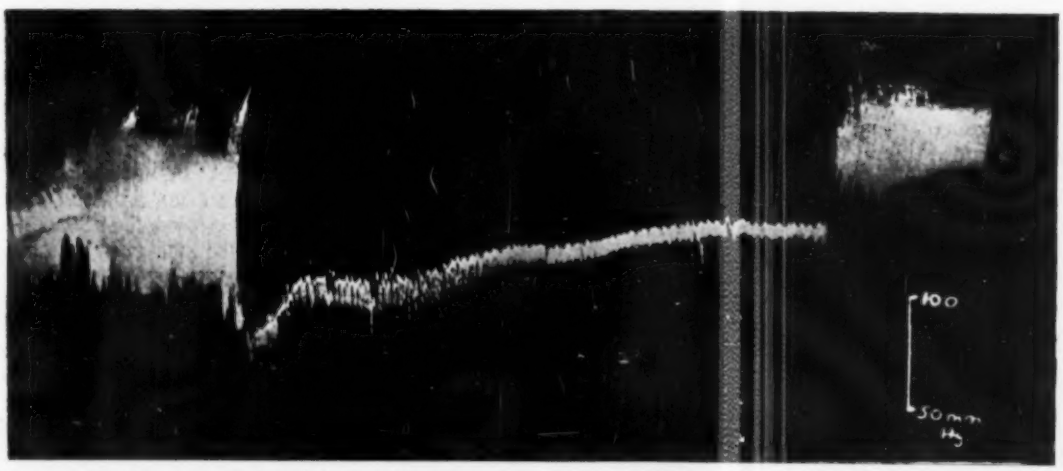

FIG. 722.—Blood-pressure tracing of dog receiving 216 c.c. per minute through the azygos vein with the cavæ clamped off.

blood from the cava by means of a pump only succeeded in quickly emptying this vein, and a pause of some minutes was required before any more blood could be obtained. That is to say, the blood had to be allowed to seep into the cava and accumulate there to the capacity of that reservoir before any venous return could be obtained. By gravity this seepage into the cava was more steady and even. Under the conditions of the experiment it seems that a general pooling effect, especially in the vast tissue and muscular capillary network below the diaphragm, is the only reasonable suggestion in explanation of the observations. The conditions introduced by the caval shunt simply allowed blood to drain from the head and neck faster than it was being replaced. This blood drains into the cava below the diaphragm but does not increase the venous return, since, the cava being filled, the great tissue and muscle pool which supplies the cava seeps into this vessel at a rate unconnected with its rate or extent of emptying It is this rate of seepage into the caval reservoir which controls and limits the venous return. The question may be raised as to what fraction of the heart's output will tend to go down the aorta instead of up the great head and neck vessels, especially when the head is raised. Although there has been no chance to determine this, the point has not escaped us. In this connexion we have persistently observed a marked constriction of the aorta, and especially of the descending aorta, taking place as soon as the heart is short-circuited. Its diameter, gauged by external measurement, is reduced to less than one-quarter of its original diameter.

The contrast between the dogs on low flows with loss of reflexes, and those on the higher flows which retain their reflexes and general tonus, is remarkable. In the latter the blood-pressure is on the average about 100 mm. Hg, a level observed in many quite normal dogs, on arrival on the experimental table, before being subjected to any manipulation beyond insertion of the carotid cannula. Before the flows used in these series had been selected a number of experiments was made in order to study the changes which might occur with the introduction of flows of increasing size. It was observed that the blood-pressure remained low—in the region of 30 to 50 mm. Hg, until a flow of 150 c.c. per minute had been reached. At this point, for the first time, the reflexes were observed to remain throughout the experiment and the pressure, instead of showing the usual drop, remained at about 100 mm. Hg. This observation suggests that there is a minimal blood-pressure above which the reflexes and general tonus are fully active and below which they cannot function. This minimal blood-pressure is observed to be dependent upon a certain minimal critical return of blood throughout the heart. The observation that a flow of 150 c.c. per minute is a significant one in survival has been arrived at by Eckstein, Graham, Liebow, and Wiggers (1947) in quite another way. Working on inferior caval flows, following acute reduction in blood-volume by hæmorrhage, they observed that their dogs would not survive a reduction in blood-volume which reduced the flow through the inferior cava below 150 c.c. per minute, and they state that this is the minimal critical level for sustaining the heart.

In many ways our dogs with the venous return to the heart severely restricted represent dogs whose functional blood-volume has been temporarily reduced by acute hæmorrhage. This far our work is in accord with Eckstein's results. He does not recognize, however, that it is just at this particular flow that the reflexes are maintained, and below this are unable to function, although not extinguished beyond immediate recovery upon re-establishment of the circulation. It is the fact of this particular flow being the minimal critical return upon which the blood-pressure and other reflexes can operate, which makes it possible for their dogs to recover. It is not, as is stated in Eckstein's paper, the minimal critical level for sustaining the heart, for we have already shown that brain and heart, and presumably the other essential organs, can be maintained for at least thirty minutes on flows as low as 90 c.c. per minute with complete, immediate recovery of all functions as soon as the main circulation is restored (Andreasen and Watson, 1952).

Some comment upon the fact frequently observed in our experiments—that respiration fails before the heart in those cases in which death takes place—has an historical as well as a present interest. In general, we have observed that if the heart stops, but respiration continues, then on several occasions a simple stroking of the region of the sino-auricular node is enough to set the heart in motion again. Occasionally two or three gentle pressures with the hand, to help empty the ventricles, were required in addition. If the heart could be started within four minutes all was well, otherwise respiration failed very soon after. This, of course, is a well-known fact. When, however, respiration fails first it is commonly the end, even though the heart goes on beating strongly for some time. In only rare instances could we re-start respiration once it had ceased under our experimental conditions. When a few breaths were induced they were gasping and irregular and faded out again very soon.

In the third volume of his works, John Hunter refers to some experiments he carried out on the effect of artificial respiration on the action of the heart. His conclusions were that :—

a. Too great filling of the lungs stopped the heart in a very full state, and at least twice the normal size ;

b. Cessation of artificial respiration caused the heart to slow and to stop.

c. If artificial respiration is recommenced the heart beats at first slowly, and then faster, until normal rate ensued.

He then makes the following remarkable comment : " I believe this experiment cannot be reversed : we cannot make an artificial circulation, so as to know that if we stopped the heart's action we should as readily stop the respiration, and on reproducing the heart's motion, respiration would take place ; but if we could do this, I doubt very much its being attended with equal success, because I believe that in all deaths respiration stops first ; however, it must be supposed that if the heart stopped for any length of time, respiration would also stop." Now, from the desire Hunter expresses of finding a way of arranging an artificial circulation it would seem that he had thought a great deal about

this idea and may, perhaps, have made some attempts to put it into effect. He says " We cannot make an artificial circulation". There is in this no mere suggestion of an idea but a statement which, judging from the character of the rest of his work and his known attitude towards ideas, makes it probable that he had actually made a trial. Accidentally we seem to have set up just the sort of experiment which Hunter would have liked to have at hand to test out his inferences.

It will be noted that for the study here described we have used the original azygos standard experiment and this same preparation is now serving for other purposes in solving problems concerned with the ultimate one of obtaining a dry heart for intracardiac surgery. It seems that there is a suggestion here that this whole animal preparation might serve the physiologists also for a number of studies in connexion with restricted blood-flow and organ survival.

Utilization of the fact of survival for a short time being certain on the azygos flow alone, has served a definite purpose in making the dissection of the aorta from the pulmonary at the base of the heart a safe procedure. (Andreasen and Watson, 1953.) Normally, with the full flow going through the vessels, this dissection will more often than not result in a small tear of the thin stretched wall of the main pulmonary trunk, and there is little possibility of repair under these circumstances. By clamping the cavæ and leaving the azygos open before attempting the separation of these vessels, the flow is so restricted that there is now ample room for dissection with safety between the narrowed vessels.

It is suggested that the azygos data might well be applied to another practical surgical problem—that of removal of a pulmonary embolus. Admittedly this is not a complication often seen in practice in highly organized surgical centres since the introduction of controlled anticoagulant therapy, together with the recognition of the origin of the majority of these emboli. However, it is still an accident which can arise anywhere, and in isolated practice especially. The great hazard of the Trendelenburg operation has always been the necessity for obstruction of the main pulmonary trunk at the base of the heart. The extremely short time during which the obstructing agent may be left in place makes for rushed work and may lead to incomplete removal, dislodgement of fragments, and other fatal accidents. It is suggested that the cavæ should be first clamped off, leaving the azygos open, before any attempt is made to open the pulmonary. Reduction of the stream through the heart will reduce the pressure of blood forcing the clot onwards. The vessel itself will go slack, making it easier to open and also to sew up afterwards. Knowing that it is possible for an animal to survive short periods on the azygos flow alone, time can be taken to try and remove the clot *in toto*, as well as to make a secure suture of the opening into the vessel afterwards. Again, the return of a normal flow can be controlled by graduated release of the clamps on the cavæ, so that testing of the suture line for weaknesses may be carried out systematically. What remains is to discover if the human can survive for a short time on the human azygos flow alone, and for how long with safety. The data obtained in the course of our experiments will certainly serve the surgeon in offering a little guidance and perhaps encouragement.

ADDENDUM

At the time of writing the first paper on the ' Azygos Factor ', technical assistance for Van Slyke analyses was not available. Since then these estimations have been undertaken through the great kindness of neighbouring workers and the results are recorded in *Table III*. There was some difficulty in obtaining the samples until the technique described—catheterization of the ascending aorta and of the right auricle—was adopted. Polythene tubing, fine enough to fit tightly over the shaft of a No. 6 Record serum needle, was used. With a needle in the end to be left outside the vessel, a length of this tubing was passed down the left carotid until the waiting finger in the thorax could locate the other end in the aortic arch. It was easy to manipulate this end so that it lay directly over the aortic valves. On the right the external jugular was used to pass the same type of tubing with needle attached down into the right auricle. Each needle was fitted with a paraffin-prepared blood-sampling syringe, to make the system air-tight. The only point to watch was the detaching and re-attaching of syringes, to ensure that air did not get into the tube or syringe. This did not prove too difficult. The next point was that samples had to be no greater than 2 c.c. because the abstraction of several samples of larger size would, at these small flows, fatally deplete the amount of circulating blood.

Table III.—Blood-oxygen Values during Natural Azygos Flows with Survivals
(*Vols. per cent*)

Experiment Number	Chest open before Clamps	9–15 min. after Clamps	Approx. 30 min.	4–5 min. after Release
1	A. 22·09	24·6	20·5	18·25
	V. 15·9	8·0	2·24	16·5
2	A. 23·6	—	22·17	—
	V. 20·3	—	4·1	—
3	A. 17·6	—	14·6	15·85
	V. 11·76	—	2·07	14·6

As far as circumstances permitted, samples were taken: (1) before clamping the cavæ; (2) nine to fifteen minutes after clamping; (3) just before release of the clamps at the end of thirty minutes; (4) five minutes after re-establishment of the circulation. The extreme reduction of the venous sample towards the end of the experiment, the high saturation of the arterial one, and the very high venous value five minutes after release of the cavæ are notable.

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SHORT NOTES OF RARE OR OBSCURE CASES

PRIMARY OVARIAN PREGNANCY

By C. R. STROTHER-STEWART, Newcastle General Hospital

The condition of primary ovarian pregnancy, although now more accurately recognized, is still of sufficient rarity to be worth recording. From recent literature (Ismail, 1950; Toplack, 1950; Turner and Weiss, 1951), together with case reports later than March, 1951 (Lajoie, 1951; McIntyre, 1951), and including the present case, the total now recorded in the literature is at least 125. This total does not include cases described in other articles in the medical press which I have not been able to see (Postoloff, Nichols, Hellriegel, and Frankzac, 1951; Arronet, 1951; Arenas and Canale, 1951; Pearson and Horton, 1951).

CASE REPORT

Mrs. E. H. (Case No. 16160), aged 28, para 2, was admitted to Newcastle General Hospital on Dec. 11, 1951, as an acute abdomen. Four days before admission she had lower abdominal pain—likened to dysmenorrhœa—associated with sickness. This lasted two hours. The

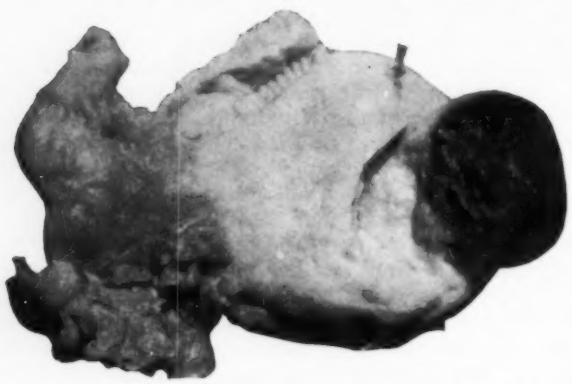

Fig. 723.—Macroscopical photograph of left ovary, showing from left to right, fimbrial end of Fallopian tube, ovary, corpus luteum, hæmatoma containing chorionic villi.

night before admission at 10.0 p.m. she developed severe lower abdominal pain, for which she took aspirin and went to bed. Two hours later she woke up with much more severe pain, and felt dizzy on sitting up. A few hours later she felt pain across her shoulder-tips. Her symptoms persisted up to the time of admission at 12.25 p.m. in the afternoon. The bowels had previously moved normally. There were no urinary symptoms. Her periods were normally regular 5/28. L.M.P. normal on Nov. 9, 1951—present period 4 days late. No intermenstrual discharge.

On Examination.—The patient was well nourished, rather pale, and anxious. Apyrexial—pulse 88/min. No abnormality of respiratory, cardiovascular, or central nervous systems. The abdomen was tender and guarded in R.I.F., with slight tenderness and minimal guarding in L.I.F. Some dullness in R. flank. No masses felt. No abdominal distension. Bowel sounds present. P.R. acute tenderness on movement of the cervix, and a boggy acutely tender mass in the pouch of Douglas.

A provisional diagnosis of ruptured ectopic pregnancy was made.

At Operation.—The peritoneum was opened through a lower right paramedian incision, and a very large quantity of free blood and clot was removed (approximately 2 pints). A mass about 1 in. in diameter, closely associated with the left Fallopian tube, was found. A clamp was applied to control the hæmorrhage, which was profuse. Inspection revealed that the bleeding was coming from a rounded hæmorrhagic tumour in the ovary about ½ in. in diameter, and in view of the excessive hæmorrhage occurring, it was thought to be an ovarian pregnancy. The left ovary, together with the neighbouring portion of tube, was excised. Clots were removed, and the wound closed without drainage. One pint of plasma was given during the operation, and this was followed by one pint of blood.

She made an uneventful convalescence.

Pathological Report.—This was as follows: "Normal sized ovary from which there was a projecting hæmorrhagic corpus luteum. There is a tear in the wall of the cyst and typical corpus luteum tissue at the base. (*Fig.* 723.)

"Histological examination shows a large corpus luteum compressed by a small sac of blood, containing numerous chorionic villi (*Fig.* 724). It thus appears to be an ovarian pregnancy.

"Tube is present, which shows no macroscopic abnormality. Histological examination. The two sections of the tube are normal."

DISCUSSION

The accurate diagnosis of primary ovarian pregnancy can be made if the four criteria of Spiegelberg (1878) are observed. These are: (*a*) the tube on the side of the affected ovary must be intact; (*b*) the fœtal sac must occupy the ovary; (*c*) the ovary must be connected to the uterus by the ovarian ligament; and (*d*) ovarian tissue must be in the wall of the sac. Sutton (1924) elaborated these criteria further. He also discussed the mechanism of fertilization or implantation of the ovum, and from this differentiated (*a*) primary ovarian pregnancy in which fertilization occurred in the ovary from (*b*) secondary ovarian pregnancy in which fertilization occurred outside the ovary and at a later date the developing ovum encroached upon or became adherent to the ovary. The differential diagnosis in these cases must therefore include primary and secondary ovarian pregnancy and of course ruptured lutein cyst. It is possible that a few patients with 'ruptured lutein cysts' are in fact early ovarian pregnancies. The original diagnosis by the pathologist in our case was this, but at operation it seemed to us that the hæmorrhage was far too excessive for such a condition.

It is not certain how the ovum in a primary ovarian pregnancy is fertilized. It was thought that the ovum which had become fertilized in the abdominal cavity settled on an endometrial rest in the ovary. However, in many cases there has been no evidence of endometriosis. A more likely possibility is the fertilization of the ovum as it still

lies within a ruptured corpus luteum. The ovum then develops rapidly, but in the process destroys itself at an early stage by causing hæmorrhage into the ovary around it. If it were not for this, the ovarian pregnancy might well proceed to term, because the ovary will permit stretching relatively easily.

A consideration of the life history of a primary ovarian pregnancy will explain the clinical course of the condition. It thus presents in one of two ways, either as a dramatic incident, in which case it is impossible clinically to distinguish it from any other ruptured ectopic pregnancy, or in a more insidious form, characterized by pain which might be slight and transient, associated with absent or irregular menses. In its dramatic form the pregnancy ruptures into the peritoneum and the hæmorrhage is not self-limiting. In a less dramatic form it may rupture into the broad ligament. In many cases, however, the leak has been slight and readily sealed off by adhesions to neighbouring structures. In some cases it has existed simply as a blood cyst in the ovary. Very occasionally it has coexisted with a normal uterine pregnancy, and Arthur Hertog reported such a case in a discussion on ovarian pregnancy (Lajoie, 1951). In these less dramatic forms the condition often becomes static and may give rise to no further trouble. It is possible that some of these cases are never diagnosed at all, but if this was at all common this condition would be more frequently recognized in hospitals where post-mortem examination in all cases is a routine. Not infrequently, however, operation for broad ligament or ovarian cyst is performed in these cases, and the true pathology only found when the condition is exposed.

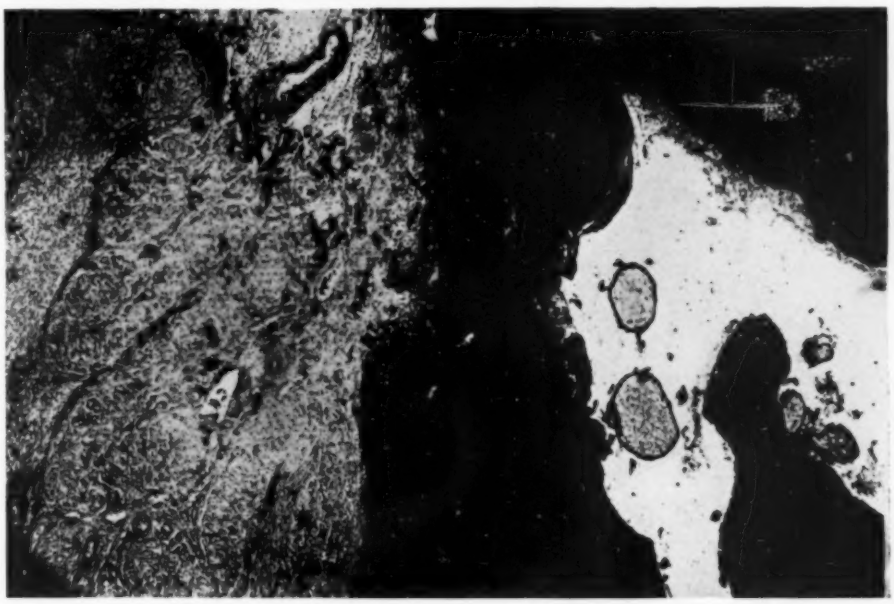

FIG. 724.—Photomicrograph showing from left to right typical corpus luteum tissue, hæmatoma, and chorionic villi.

SUMMARY

A case of primary ovarian pregnancy is described. Its incidence is discussed.

My thanks are due to Mr. J. K. McCollum, under whose charge the patient was admitted, for permission to publish this case. Dr. George Tomlinson was very helpful in demonstrating the pathology for me. The macroscopical photograph was taken by Mr. S. Gordon Hilton, A.R.P.S.; and Mr. A. Hall, from the hospital laboratory, kindly prepared the photomicrograph.

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FIBROSARCOMA OF THE TONGUE

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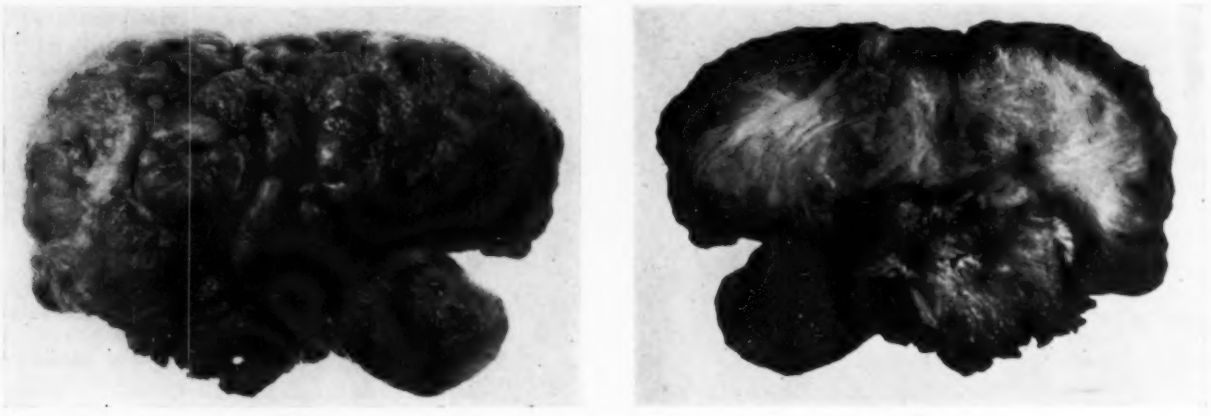
CASE REPORT

HISTORY.—The patient, a man of 75 years, first noticed slight difficulty in speaking in May, 1949. He attributed this to ill-fitting dentures. He noticed no pain or swelling of the tongue at that time. In September his dentures were remodelled, after which his speech improved; the tongue still felt normal.

In October, 1949, three weeks before admission, he had difficulty in eating and in speaking clearly. A few days later he noticed swelling of the tongue; this increased rapidly and the night before admission he had a choking attack. His general health was unaffected.

In 1940 he had had a squamous-cell carcinoma of the right lateral border of the tongue; this was confirmed histologically and was treated by diathermy excision followed by interstitial radium, with a satisfactory result.

ON EXAMINATION.—The patient was in great distress with respiratory difficulty, the mouth being held half-open to accommodate a massive tumour. Although the tumour was evidently arising from the dorsum of the tongue, it was so large that only the tip of the tongue could be seen. It extended back into the vallecula and forwards to within 2 cm. of the tip, the anterior unaffected part of the tongue being very œdematous and swollen. The tumour was rounded, with an irregular lobular surface covered by greenish exudate, and of firm consistence. Movements appeared to be limited by the size of the mass rather than by deep fixation. The mouth was edentulous. There were no palpable cervical lymph-glands.



A B

FIG. 725.—Glossectomy specimen. A Right lateral aspect; B, Cut surface of right half. (× ⅔.)

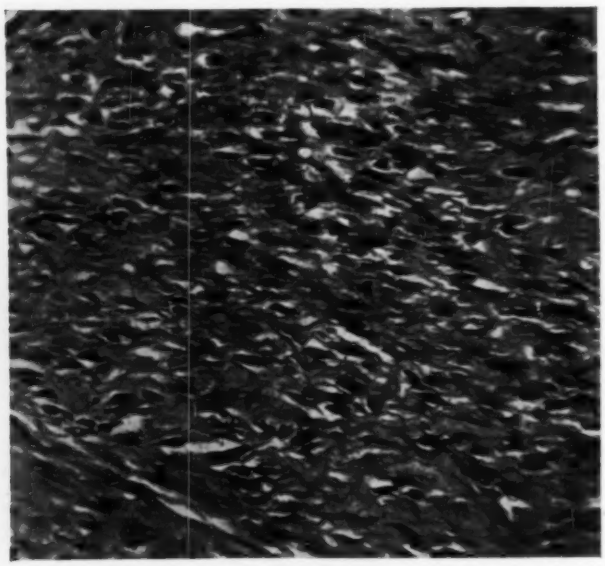


FIG. 726.—Microscopical appearance of the tumour. (× 200.)

INVESTIGATIONS.—

Biopsy.—Section shows a fibrosarcoma composed of bundles of elongated and fusiform cells with much collagen; a few mitoses are present.

Wassermann and Kahn reactions were both negative.

OPERATION (Nov. 14).—Total glossectomy. Anæsthesia was by pentothal and cyclopropane; an endotracheal tube had previously been passed via the nose after cocainization of the larynx. The tumour filled the mouth so completely that it was impossible to see normal tongue. It was therefore split anteriorly in the midline and separated so that the small area of dorsum of the tongue near the tip came into view. This also was split and pulled upwards so that the floor of the mouth on the left side could just be seen; the mucosa here was incised with a fine diathermy needle and the lingual artery divided. The same procedure was adopted on the right side, and the tongue gradually mobilized in a backward direction. Tongue and tumour could finally be pulled forward enough for the vallecula to be seen and the whole specimen was removed in one piece. Some of the mucosa in the floor of the mouth was sutured to the muscles, but the bulk of the floor of the mouth was left uncovered.

The patient was fed on a 2000-calory diet by means of a nasal tube for 8 days, and had 50,000 units of penicillin

4-hourly during this period. Post-operative recovery was uneventful.

REPORT ON SPECIMEN.—The specimen consists of the tongue with a large rounded mass arising from the dorsum, measuring 8·5 cm. long, 7 cm. wide, and 3 cm. thick. The surface is lobulated, with rounded margins which overlap the broad pedicle on all sides. The cut surface is firm and silvery-white, with a whorled and streaked pattern; there is a deep red peripheral zone of vascular engorgement ½ cm. thick. The line of demarcation from the tissues of the tongue is not clearly defined.

Histology.—Sections show a well-differentiated fibrosarcoma composed of whorled bundles of fibrous tissue, hyalinized in places; the cells are uniform and elongated, with few mitoses, and there are a fair number of dilated thin-walled blood-vessels. The surface is covered by necrotic debris with underlying acute inflammatory changes. At its base the growth is invading the tissues of the tongue and the margin is therefore ill-defined, though the line of excision appears to be clear of it. The histological appearance suggests a tumour of relatively low malignancy. Posterior to the tumour the squamous epithelium of the tongue shows the changes of leucoplakia.

FURTHER COURSE.—There is no sign of local recurrence or of metastasis after three years. The patient can talk intelligibly and has no difficulty in eating.

DISCUSSION

Fibrosarcoma of the tongue is a rare condition. Most reports in the literature are of single cases; recent reviews of the condition include those of Hofman, Martin, and Marti (1947), and of Ross (1935).

A striking feature of this case is the previous history of malignancy and irradiation of the tongue nine years before. To develop two different malignant tumours of the tongue, one of which is of rare occurrence, is a remarkable coincidence, and suggests the possibility of some aetiological relationship. Irradiation, which is known to be carcinogenic under certain circumstances, may have influenced the later development of sarcoma.

The only previous reference to this found in the literature was that of Gricouroff (1937), who describes 2 cases of fibrosarcoma of the tongue following previous irradiation. In one case there was a three-year interval between treatment of a carcinoma by interstitial radium and the development of the fibrosarcoma. In the other case there was leucoplakia and a "papilliform growth" which was treated with radium followed by local excision; seven years later radium treatment was given a second time for ulcerated leucoplakia, and five years after this a fibrosarcoma developed. The aetiology is discussed and a view similar to that above is expressed.

SUMMARY

A case is described of fibrosarcoma of the tongue following previous irradiation of a carcinoma of the tongue. Total glossectomy was followed by freedom from recurrence for three years.

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SMALL-BOWEL OBSTRUCTION FOLLOWING ANTECOLIC PARTIAL GASTRECTOMY

BY J. B. OLDHAM, V.R.D., LIVERPOOL

IN the July, 1952, issue of the JOURNAL Professor Stammers recorded a case of obstruction of the intestine after an antecolic partial gastrectomy as the result of the small gut passing through the gap between the anastomosis in front and the transverse colon behind. He also reported a similar case which had been under the care of Mr. Doolin, of Dublin, and mentioned that he had heard of a further case.

In Professor Stammers's case, obstruction came on nine days after the gastrectomy, and in Mr. Doolin's case there were only five days between the gastrectomy and the acute obstruction.

I wish to record a case in which obstruction first appeared five to six months after partial gastrectomy.

CASE REPORT

H. W., aged 49, a medical librarian, began to suffer in 1940 with pain after meals in the epigastrium followed by vomiting. With dieting and the use of alkaline powders his symptoms rapidly improved and he had no more trouble until 1945, when his symptoms recurred.

This time the indigestion did not respond to treatment so well and kept on recurring with remissions of a few weeks or months. He noticed that sometimes he would vomit food taken a day or two previously. He was admitted into a medical ward as an emergency on Dec. 6, 1948, as he had collapsed twice, following a bout of vomiting. He was found to be grossly dehydrated and his urinary chlorides were very low. With intravenous salines he rapidly improved. Radiological examination showed signs of a duodenal ulcer with some delay in emptying of the stomach. A gastric test-meal showed a very low acidity. After four weeks in hospital he was discharged to his home and resumed his work.

In July, 1949, he returned to the medical out-patient clinic and said that his symptoms had recurred within a week of leaving hospital in January, 1949, and had continued with short remissions ever since then.

He was admitted to the medical wards and was later transferred to the surgical wards. After appropriate preparation an operation was performed on April 26, 1950. A large ulcer was found on the posterior wall of the duodenum invading the pancreas. An extensive antecolic partial gastrectomy of the Polya type was performed with a Hoffmeister valve.

He made a good recovery from operation and fifteen days later was discharged from hospital. During the next few months he was often seen by me in the library where he worked and was always enthusiastic over the excellence of his health and digestion.

On Nov. 4, however, he was once more admitted into hospital in an emergency. He said he had been perfectly

well until the last two months, when he started to have pain in the epigastrium and left lower abdomen. Soon after his pain restarted he had an attack of vomiting and this had happened several times. The vomit was brownish and sometimes contained some blood.

For three days prior to admission to hospital he had been vomiting and had passed no flatus or fæces.

The patient was clearly very ill and dehydrated. There was obvious bulging in the left flank and hypochondruim, while the rest of the abdomen was flat. On palpation it was found that the bulge was due to a tender, slightly mobile mass which occupied the left half of the epigastric region and went well round into the left loin. The mass was dull to percussion: no sounds could be heard on auscultation of the abdomen. On rectal examination nothing abnormal could be felt. An enema produced no fæces or flatus, but was returned slightly blood-stained.

After a few hours spent on preparation with saline infusions and gastric aspiration, the abdomen was opened.

The peritoneal cavity contained a moderate amount of blood-stained, bile-stained intestinal contents and gas. A large part of the small intestine had herniated into the lesser sac between the transverse colon behind and the anastomosis in front. The proximal limb of the jejunum going to the anastomosis was tightly stretched over the mass of herniated intestine: it was plum-coloured, its serous coat had split right along it, and at one point it was quite necrotic and had perforated.

The herniated intestine was reduced gently and it was then found that one loop, about 2 ft. long, was quite gangrenous and had to be resected; an end-to-end anastomosis was done.

It was clearly impossible, in view of the patient's condition, to resect the gangrenous limb of the anastomosis and therefore the gangrenous portion was invaginated and the whole loop covered with a free omental graft. The hernial opening was closed in the way Professor Stammers described and the abdominal wound was sutured with a corrugated drain.

During the operation the patient's condition had deteriorated badly and for the next twenty-four hours his pulse was scarcely countable. However, he began to improve and on Nov. 7 and 8 he passed flatus. On Nov. 9 he began to discharge bile-stained fluid from the incision.

In spite of every effort being made to control the fistula, the patient's condition gradually worsened and he died on the eleventh post-operative day.

Acute or chronic obstruction of the type in this case, and in those reported by Professor Stammers, probably occurs much more frequently than has been recognized and its prevention should be ensured by sealing off the opening.

REFERENCE

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TRAUMATIC RUPTURE OF THE STOMACH

BY A. G. ELLERKER, LONDON

TRAUMATIC rupture of the stomach is an unusual condition in civilian practice in this country. Authorities disagree as to whether it occurs more frequently in a pathological organ or in the normal viscus. When the rupture is extensive there is usually damage to other organs. The following case is considered worthy of reporting in view of the nature of the injury, the degree of rupture, and absence of damage to the neighbouring structures.

CASE REPORT

G. L., a schoolboy aged 14 years, was admitted to the Royal Free Hospital on March 12, 1952, complaining of upper abdominal pain. He had been playing in the street after having a large lunch and had slipped from a guard rail at the edge of the pavement, while attempting to balance on it. In falling a total distance of about 3 ft. he had struck his abdomen against the upper rail. He was immediately seized with severe upper abdominal pain which persisted until his admission. He complained of nausea, but had not vomited.

ON EXAMINATION.—A healthy well-developed boy, lying still in bed and obviously in pain. He was pale, but not clammy; temperature 96·8° F., pulse-rate 124 per minute and of good volume, blood-pressure of 120/90 mm. Hg.

There was a small bruise 1½ in. in diameter to the lateral side of the right rectus muscle, just below the costal margin. The abdomen was uniformly distended and did not move on respiration. There was generalized guarding, with board-like rigidity in the epigastrium and both hypochondriac regions. On light percussion there was dullness in both flanks, liver dullness was absent, and gentle side-to-side movement gave rise to an audible splash. Bowel sounds were absent. On raising the foot of the bed, he complained of pain in both shoulders. Generalized tenderness was noted on rectal examination. No other injuries were found clinically, and examination of all other regions and systems was negative. A diagnosis of "ruptured hollow viscus, probably stomach" was made. After commencing intravenous fluids and insertion of a Ryle's tube, operation was undertaken.

AT OPERATION.—Under general anæsthesia (pentothal, flaxedil, N_2O, and oxygen) a right paramedian incision, 6 in. long, was made in the epigastrium. On entering the peritoneal cavity it was seen to be flooded with undigested stomach contents and all surfaces were the seat of an intense inflammatory reaction. The stomach was completely severed by a laceration extending round its circumference, so that the pyloric antrum lay to the right of the vertebral column and was only attached to the body of the stomach by the great omentum and the gastro-hepatic omentum. There was minimal bleeding from the cut edges of the stomach. A three-layer anastomosis between the cut ends was performed, peritoneal toilet carried out, and all other abdominal viscera examined carefully for injury. No associated lesions were found and the abdominal wall was therefore closed in layers. Drainage-tubes of soft rubber were inserted through separate stab incisions into the lesser sac, Morison's pouch, and the pelvis.

Post-operatively continuous intravenous infusions of saline and blood were given, and continuous gastric suction instituted. Penicillin 500,000 units and streptomycin 0·75 g. were injected intramuscularly.

On recovering consciousness, his condition appeared to be satisfactory although his blood-pressure was only 90/60 mm. Hg. Twelve hours after the original injury and approximately seven hours after the operation had been completed, he suddenly became comatose and his

blood-pressure could not be recorded. Methedrine 1·5 c.c. and coramine 2 c.c. were given with temporary improvement for four hours, when he relapsed again into coma and died.

At autopsy the absence of other lesions was confirmed and the suture line was found to be intact. All peritoneal surfaces were still intensely inflamed and a considerable quantity of residual undigested food was found in the peritoneal cavity. Both kidneys showed classical severe cortical ischæmia with congestion of the medulla. Both macroscopically and microscopically the stomach was normal.

My thanks are due to Miss G. Barry for permission to report this case, which was admitted under her care.

A DISLOCATED EYE

By CYRIL C. SLACK

SENIOR ORTHOPÆDIC REGISTRAR, NOTTINGHAM CITY AND CHILDREN'S HOSPITALS

THERE must be no limit to the variety of injuries which the human body receives from time to time.

The following case admitted to the Nottingham Children's Hospital would seem sufficiently unusual to warrant publication.

CASE REPORT

T. W., aged 7 years, in May, 1951, fell through the glass roof of a factory. He sustained an over-riding transverse fracture of the left humerus and multiple lacerations. One involving the left eye had split open the lower lid and, in spite of gentle swabbing, the globe of the eye could neither be seen nor felt. Instead, an ugly piece of glass, vertically disposed and firmly fixed, was protruding from a mass of blood-clot.

FIG. 727.—Radiograph showing the fragment of glass wedged into the orbit.

X-ray examination showed a large fragment of glass almost filling the orbit (*Fig.* 727).

The only possible opinion was that the globe of the eye must have been destroyed.

At operation on the same evening, the piece of glass was extracted. It was so firmly wedged that this could not be done without splintering the free margin (*Fig.* 728). As soon as the foreign body was away, the eye sprang miraculously into view from the outer side, and the lower lid was then sutured.

His subsequent progress was very satisfactory. One year later he had neither squint nor diplopia, although a slight deformity of the lower lid has persisted (*Fig.* 729).

An extensive search of the literature has failed to disclose records of a similar case.

Even his fractured humerus united perfectly.

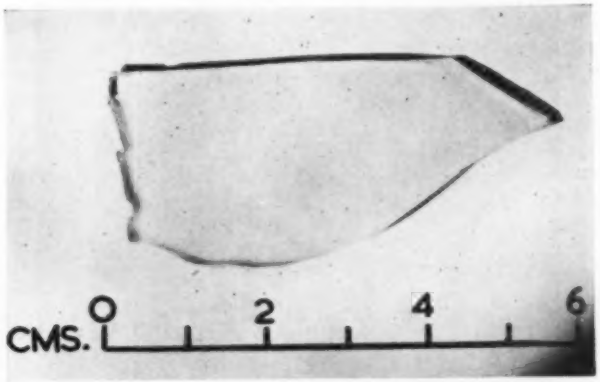

FIG. 728.—The foreign body after extraction, to show its size.

FIG. 729.—The scar as it appeared one year later.

I have to thank Mr. A. N. Birkett for permission to publish this case; Mr. Hamilton Booth for accepting the ophthalmic responsibilities; and the Photographic Section of the Nottingham General Hospital for the plates.

AN OVARIAN DERMOID CYST PERFORATING THE URINARY BLADDER

By KENNETH WOOD, Leeds

Perforation of the urinary bladder by an ovarian dermoid is a recognized but rare complication. In the case to be described the classical passage of hair in the urine occurred.

CASE REPORT

History.—A female, aged 37 years, was seen in May, 1952, in the out-patient department with a five-weeks' history of scalding and frequency of micturition. An investigation of her cystitic symptoms was commenced. Physical examination was negative; her urine contained pus cells and on culture a profuse growth of *B. coli* was obtained. An intravenous pyelogram was performed and reported on as normal apart from a small calcified body in the right side of the pelvis. The patient ceased to attend out-patients, but her own doctor gave her a course of sulphadiazine. Her symptoms did not settle, and in addition she developed suprapubic pain and urinary incontinence. Three weeks after having been seen as an out-patient she was admitted to hospital.

On Admission.—The patient appeared acutely ill. Her temperature was 101·6° F., and she had urinary retention, the bladder extending to the umbilicus. This was relieved by catheterization; the urine obtained was foul smelling and contained abundant pus cells. Pelvic examination revealed a tender swelling in the right fornix.

The patient was immediately placed on a course of penicillin and streptomycin, but this was stopped after forty-eight hours because the urine on culture was found to be sterile.

When the Ward Sister was preparing to obtain another catheter specimen of urine she noticed some hairs protruding from the patient's urethra. These hairs were pulled upon and without much difficulty a pear-shaped mass of hair 3 × 1½ in. descended the urethra from the bladder. The hairs in the mass were found to be in 10–12-in. lengths and of similar colour and texture to those on her head. They were matted together by sebaceous material.

Cystoscopy was carried out and although the bladder was difficult to see because of a great deal of loose hair and sebaceous material, a defect was found on the right wall of the bladder from which hair was projecting. A diagnosis of an ovarian dermoid cyst perforating the bladder was made.

Fig. 730.—The specimen removed at operation, showing the ovarian cyst with attached cuff of bladder mucosa around the defect in the bladder wall through which hair is protruding.

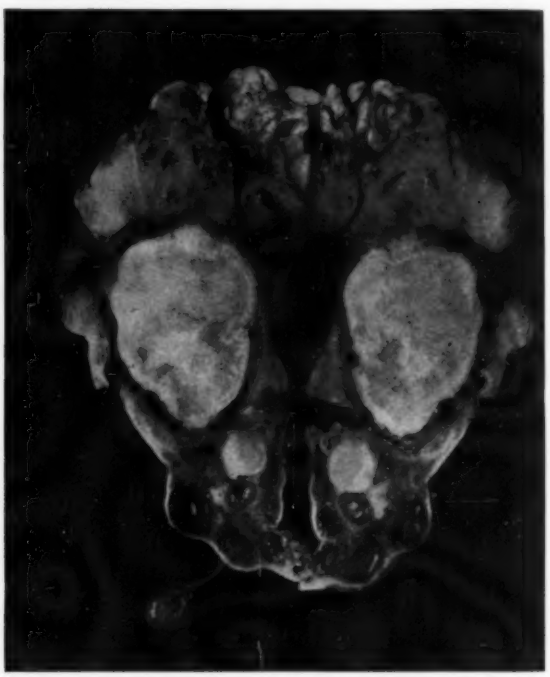

Fig. 731.—The specimen sectioned through the perforation into the bladder, showing the protruding hair.

At Operation.—A laparotomy was performed. The left ovary was found to be much enlarged, sausage-shaped, and adherent to the right dome of the bladder. The right ovary was normal. The left ovarian tumour was removed with a cuff of bladder wall around the adherent area, and the bladder emptied of remaining hair and sebaceous material (*Fig.* 730). The bladder defect was then closed.

Post-operative course was uneventful. She had a five-day course of penicillin and streptomycin and continuous bladder drainage was maintained for ten days by an indwelling self-retaining catheter. Urine examination on discharge showed the urine to be sterile, but still to contain a few pus cells.

She has been seen since discharge from hospital and her condition is satisfactory in every way.

PATHOLOGICAL REPORT.—

N.E.—The specimen consists of a piece of bladder adherent to inflamed fat and a cyst which is sausage-shaped. A thick strand of hair projects from the cyst through a hole in the bladder wall. There is a small piece of bone of indeterminate shape in the centre of the ovarian mass. (*Figs.* 731, 732.)

FIG. 732.—A radiograph of the specimen showing radio-opaque tissue.

Histology.—A wedge-shaped piece of tissue was taken from the cyst wall. From without inwards are seen :—

1. A rim of ovarian tissue in which are primordial follicles.
2. A zone of granulation tissue in which are spaces lined by foreign-body giant cells.
3. A squamous epithelial layer with keratinization.

No hair follicles are seen in the area of the section. These appearances suggest that a simple dermoid cyst of the ovary was ruptured and provoked a foreign-body giant-cell reaction with resulting adhesion to the bladder and final perforation. There is no evidence in the piece seen of any malignant change.

DISCUSSION

Fechner (1912), according to Geist (1942), found that among 367 ruptured ovarian neoplasms 211 ruptured into the peritoneal cavity, 51 into the intestines, 34 externally, and 26 into the bladder. This total number of ruptured ovarian tumours included all kinds of cysts, benign and malignant. No figure is quoted for dermoid cysts, but Geist mentions that dermoid and malignant cysts of the ovary are those most likely to penetrate a hollow viscus.

Wallace (1700) recorded the first case of pilimiction. Clado (1895) collected 18 cases of ovarian dermoid cysts perforating the bladder in which the sole symptom was the passage of hair in the urine (pilimiction). Quinby (1919) described 3 cases of ovarian dermoid cysts perforating the bladder.

Three further cases have been described in the more recent literature. Shik and Char (1937) described a woman who presented with cystitis. Cystoscopy revealed malformed teeth in the bladder and a defect in the bladder wall near the fundus through which hair protruded. Laparotomy revealed a dermoid ovarian cyst perforating the bladder.

Carter, Thomas, and Pearse (1939) described a patient who presented with a prolonged history of frequency and dysuria culminating in the passage of hair from the urethra. Subsequently, the patient passed gas and fæces by the same route. In this case the dermoid cyst of the ovary had ruptured into both the sigmoid and urinary bladder.

Townsend (1939) reported a case of dermoid cyst of an ovary which ruptured into the bladder and in which the presenting symptom was a severe cystitis. This case was unusual in that the ovarian dermoid cyst started to grow within the cavity of the bladder and the diagnosis was not apparent until a biopsy was made endoscopically. The dermoid was of a benign type.

Thus when a dermoid cyst of an ovary penetrates the bladder there is always a cystitis resistant to treatment. The passage of hair in the urine does not always occur, but when it does it is diagnostic of the condition.

SUMMARY

A case is described in which a dermoid cyst of an ovary ruptured into the bladder. The literature is briefly reviewed.

The major surgical procedure was carried out by Mr. H. S. Shucksmith and Mr. F. P. Raper. The case was admitted under Mr. Shucksmith's care and I would like to thank him for encouraging me to write this paper and Mr. Hainsworth for taking the photographs.

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REVIEWS AND NOTICES OF BOOKS

An Atlas of Surgical Exposures of the Extremities. By SAM W. BANKS, M.D., and HAROLD LAUFMAN, M.D., Ph.D., Northwestern University Medical School, Chicago. 7¼ × 10¾ in. Pp. 391 + xviii, with 179 illustrations. 1953. Philadelphia and London: W. B. Saunders Co. 75s.

THIS pictorial atlas has been designed by the authors to initiate the student and house surgeon into a branch of surgery which is sadly neglected and poorly explained in most text-books. It should also serve as a reference volume for surgeons who at times are required to operate on the extremities. Traumatic surgery is on the increase the world over and this is due to the fact that we are living in a mechanical age.

The importance of this book is due to the excellence of its illustrations. The illustrations are beautifully drawn and the various structures are hand-lettered, which makes for ease of reference and enhances the value of the illustration.

Every type of exposure on the extremities has been included in this volume. The book will take its place as one of the really useful books in surgery.

Local Analgesia: Abdominal Surgery. By R. R. MACINTOSH, M.A., D.M., F.R.C.S. (Edin.), D.A., Nuffield Professor of Anæsthetics, University of Oxford; etc.; and R. BRYCE-SMITH, M.A., B.M., B.Ch., D.A., First Assistant, Nuffield Department of Anæsthetics, University of Oxford. 5½ × 8½ in. Pp. 94, with 88 illustrations, a number in colour. 1953. Edinburgh: E. & S. Livingstone Ltd. 22s. 6d.

THIS small monograph gives a wealth of information concerning local analgesia for abdominal operations. With modern drugs and modern technique much can be accomplished with local analgesia, and the authors of this monograph have proved in a really practical manner the real worth of this form of anæsthesia.

Parkinson's Disease and its Surgical Treatment. By LESLIE C. OLIVER, F.R.C.S. (Eng.), Neurosurgeon, West End Hospital for Nervous Diseases, London; Royal Northern Hospital, London; etc. 5½ × 8½ in. Pp. 87 + viii, with 12 illustrations. 1953. London: H. K. Lewis & Co. Ltd. 12s. 6d.

PARKINSON'S disease is a distressing malady and there is at present no known cure for it. Mr. Oliver has proved his point in maintaining that with a careful selection of cases of this disease Putnam's pyramidotomy in the cervical spinal cord will relieve the tremors of the arms.

This small monograph should prove of real value to any neurosurgeon who contemplates performing the operation.

The 1952 Year Book of Urology. Edited by WILLIAM WALLACE SCOTT, M.D., Ph.D. Director, James Buchanan Brady Urological Institute, The Johns Hopkins Hospital; etc. 5½ × 7⅝ in. Pp. 371, with 79 illustrations. 1953. Chicago: Year Book Publishers, Inc. (London: Interscience Publishers Ltd.) 44s.

THIS useful year book gives an excellent précis of the important American articles on urology which have appeared in the medical press during 1952. Its value lies in its small size and clear printing. It can be read in the car or train and takes up little room.

An excellent résumé of up-to-date American urology.

Operative Neurosurgery. With Emphasis on Procedures in Trauma. By ELISHA STEPHENS GURDJIAN, M.D., Professor of Neurosurgery, Wayne University College of Medicine; etc.; and JOHN E. WEBSTER, M.D., Assistant Professor of Surgery, Wayne University College of Medicine; etc. 6¾ × 10 in. Pp. 422, with 129 illustrations. 1952. Baltimore: The Williams & Wilkins Co. (London: Baillière, Tindall & Cox, Ltd.) 76s. 6d.

THIS large volume covers the whole field of neurosurgery, with special emphasis on procedures in trauma. The whole work has a practical bias and the technique of various operative procedures is well illustrated and clearly described. The illustrations are rather unique, they consist of multiple action and multiple plane drawings. These give the reader a clear understanding of the technique involved in the operations.

This book should prove of value to the student and practitioner alike, for they will gain an excellent idea of the various neurosurgical operations.

Plastic Surgery at the New York Hospital One Hundred Years Ago. With Biographical Notes on Gordon Buck. By HERBERT CONWAY, M.D., and RICHARD B. STARK, M.D. Forewords by John Hay Whitney, Stanhope Bayne-Jones, M.D., and Frank Glenn, M.D. 5½ × 8½ in. Pp. 110 + xii, with 29 illustrations. 1953. New York: Paul B. Hoeber Inc. $5.00.

THIS small monograph gives a historical sketch of New York Hospital a century ago and an account of Gordon Buck, who was one of the pioneers of plastic surgery at that time. Following the Civil War, Buck had plenty of material for facial plastic surgery.

The history of medicine in all its many and varied branches always appeals to the medical profession as it gives them an insight into the past.

This little book should interest plastic surgeons both at home and abroad.

The Principles of Neurological Surgery. By LOYAL DAVIS, M.S., M.D., Ph.D., D.Sc. (Hon.), Professor of Surgery and Chairman of the Division of Surgery, Northwestern University Medical School, Chicago, Ill. Fourth edition. 6⅛ × 9¼ in. Pp. 544, with 186 illustrations. 1953. London: Henry Kimpton. 63s.

THE fourth edition of this well-known book has been very thoroughly revised and brought up to date. There is no better book that has been written which gives in a lucid and forthright way the principles of neurological surgery.

Professor Davis has chosen his illustrations well and they all enhance the value of the text.

An excellent book for students and graduates alike.

An Atlas of Skull Roentgenograms. By BERNARD S. EPSTEIN, M.D., Assistant Radiologist, The Jewish Hospital of Brooklyn, New York, and LEO M. DAVIDOFF, M.D., Neurosurgeon to the Mount Sinai Hospital, New York City, and Director of Neurological Surgery, the Beth Israel Hospital, New York City. 6⅛ × 10 in. Pp. 415, with 315 illustrations. 1953. London: Henry Kimpton. 110s.

THE progress of neurosurgery during the last twenty years has been enormous and there are many factors which have accounted for this. One of these factors is

the value of modern radiographs illustrating not only the bony structure of the skull but also of the outlines of the ventricles, and the arrangements of the cerebral arteries.

This excellent atlas of some six hundred illustrations gives the reader a first class and up-to-date volume covering every kind of cerebral condition. The quality of the radiographs is superb and they illustrate every kind of cerebral tumour, aneurysms, calcifications, abnormal ossifications, and congenital defects. The book will become the reference volume not only for the neurosurgeon but also the neurologist. The senior student who contemplates a higher degree will find this book invaluable.

Progress in Ophthalmology and Otolaryngology. A Quadrennial Review. Vol. I. Part I—Ophthalmology. Edited by MEYER WIENER, M.D., and A. EDWARD MAUMENCE, M.D. Part 2—Otolaryngology. Edited by PERCY E. IRELAND, M.D., and JOSEPH A. SULLIVAN, M.B. 6 × 9 in. Pp. 666 + xiv. Illustrated. 1952. New York: Grune & Stratton. $15.00.

THIS volume contains various articles written by various experts in ophthalmology and these articles cover the literature on these subjects from 1946 until 1952. The purpose of this progress volume is to help beginners in these branches of surgery and those medical officers who are returning from the armed forces and who have not been able to see the literature while overseas.

Every facet in ophthalmology and otolaryngology has been amply covered and the many contributors have performed their task well.

John Abernethy. A Biography. By JOHN L. THORNTON, A.L.A., Librarian, St. Bartholomew's Hospital Medical College. 5¾ × 8¾ in. Pp. 184, with Frontispiece and 8 plates. 1953. London: Simpkin Marshall Ltd. 25s.

THIS is a delightful biography of a great surgeon, for it tells the truth and gives the reader a real sense of conditions as they were in London in the early part of the nineteenth century. It is just a century ago that George Macilwain published his memoirs of John Abernethy and much fresh material has come to light since that time.

Mr. Thornton is to be congratulated upon the way he has marshalled new facts and material concerning John Abernethy and has presented them in an interesting manner. The extensive bibliography of Abernethy's writings should prove of real value to the medical historian of the future. An excellent production.

Roentgen-diagnostics. By H. R. SCHINZ, W. E. BÆNSCH, E. FRIEDL, and E. UEHLINGER. First American edition, based on the fifth German edition. English translation arranged and edited by JAMES T. CASE, M.D., D.M.R.E., Professor of Radiology Emeritus, Northwestern University Medical School, Chicago. Volume II, Skeleton. 7⅞ in. × 10⅝ in. Pp. 869–2059, with illustrations Figs. 1184–2676 and charts. 1952. London: William Heinemann (Medical Books) Ltd. £15.

THE second large volume of this stupendous work completes, with Volume 1, the section dealing with the skeleton, and contains the index to both volumes. The illustrations number 1500 and are universally good. The two volumes cover in a comprehensive way the important subject of the skeleton in health and disease.

The subjects discussed include tumours of bone, deformities, the influence of vitamins and hormones in bone diseases, the diagnosis of diseases, malformations, and injuries of the skeleton.

The book is typical of German thoroughness and every conceivable condition of the skeleton has been conscientiously described and illustrated.

The bibliographical references are numerous and have been augmented by the translator to cover recent British and American literature.

As a work of reference this book should be in every medical library.

The History and Development of Neurological Surgery. By ERNEST SACHS, A.B., M.D., Research Associate in Physiology, Yale University, New Haven; formerly Professor of Clinical Neurological Surgery, Washington University School of Medicine, St. Louis. 5½ × 8 in. Pp. 158, with 50 illustrations, as plates. 1953. London: Cassell & Co. 30s.

THIS short history of neurological surgery is full of interest, and no wonder, because Dr. Sachs was one of the founders of the Society of Neurological Surgeons and since he gave up his Chair at St. Louis in 1949 he has concentrated his efforts on neurosurgery. Dr. Sachs' background is sound and full of interest; his work with Victor Horsely, Harvey Cushing, and Alfred Adson must have stimulated his interest in the early history of his subject.

In this monograph he traces the early development of neurosurgery from primitive times until the present day. Prehistoric trephining must have been one of the very early operations performed on man. The progress of neurosurgery was slow and it received its first fillip during the first world war when Cushing stimulated the British and American Surgeons to try his technique for dealing with wounds of the head. Following World War I progress was maintained, but the second great fillip came with World War II when special neurosurgical teams were available on all fronts.

To-day every hospital has a neurosurgeon on its staff and the turnover of cases is considerable.

Dr. Sachs has written a most interesting monograph which will not only make an appeal to the neurosurgeon but also to the medical historian.

Trichlorethylene Anæsthesia. By GORDON OSTLERE, M.A., M.B., B.Chir. (Camb.), D.A., Deputy First Assistant, Nuffield Department of Anæsthetics, University of Oxford. 4¾ × 7¼ in. Pp. 83 + viii, with 5 illustrations. 1953. Edinburgh: E. & S. Livingstone Ltd. 7s. 6d.

THE author is to be congratulated on this excellent monograph on trichlorethylene. In his usual orderly manner he reviews the history, general characteristics, and pharmacology of the drug and its clinical application in anæsthesia and analgesia.

Dr. Ostlere manages to include a vast number of references and yet maintain an easy and even style which makes the book informative and readable; an example which many other writers, particularly those from the United States of America, might follow with advantage.

The pharmacology of trichlorethylene is well reviewed, particularly with regard to the heart and respiration. The diagrams on pages 27 and 37 seem most useful in this respect. With regard to the clinical applications of the anæsthetic, the author is guilty of one small parochialism. In describing the Epstein-Macintosh obstetric inhaler, he mentions that "a second apparatus is now being designed to work automatically by thermostatic control". There are four inhalers employing this

principle already on the market but not described by Dr. Ostlere. However, this is a small criticism in an otherwise perfect monograph, which will be welcomed by general practitioners and tyro-anæsthetists with equal enthusiasm.

The quality of the printing and binding is excellent, and the price reasonable for these days.

Thoracic Surgical Management. By J. R. BELCHER, M.S., F.R.C.S., Consultant Surgeon at the London Chest Hospital; and I. W. B. GRANT, M.B., M.R.C.P. (Edin.), Assistant Physician, Edinburgh Northern Hospitals and Royal Victoria and Associated Hospitals. With a Foreword by SIR CLEMENT PRICE THOMAS, K.C.V.O. 5⅜ × 8 in. Pp. 196 + xii, with 65 illustrations. 1953. London: Baillière, Tindall & Cox. 16s.

THIS is an up-to-date surgical manual full of clinical acumen and practical information. Just the book that will prove of real worth to the many surgical registrars and senior house surgeons who have post-operative chest cases under their care. Today with the ever widening field of thoracic surgery the pre- and post-operative care becomes of prime importance.

Sir Clement Price Thomas, who writes a foreword to this book, says that "there is no doubt that it will prove great boon to those about to embark upon thoracic surgery".

This book forms a complete guide to the subject for resident surgical staffs both of specialized thoracic surgical units and of general hospitals.

Commotio Cerebri. Cerebral Concussion and the Post-concussion Syndrome in their Medical and Legal Aspects. By CYRIL B. COURVILLE, M.D., Director, Ramon Cajal Laboratory of Neuropathology, Los Angeles County Hospital, Los Angeles, California. 6¾ × 10¼ in. Pp. 161 + xiv, with 12 illustrations. 1953. Los Angeles: San Lucas Press $5.25.

THIS is a review of the various hypotheses which have been held to account for what happens to the brain when the head is injured by varying degrees of violence. Some idea of the field covered may be gained from some of the chapter headings, e.g., "Concussion in Myth, Legend and Folk Tale", "Concussion in History", "Development of the Concept of the Mechanism of Concussion", "The Traumatic Triad, Concussion, Contusion and Compression and Their Interrelationships". The monograph represents a great deal of work inasmuch as the literature of the subject is vast and much of it has obviously been consulted, but we should like to have seen more reference to British papers such as those of A. A. McConnell and to some of the war-time contributions on cerebral contusion and its treatment. The author holds that 'wet brain' may result from a temporary paralysis of the vasomotor system, and perhaps the most disappointing section of the book is that dealing with management of cases of head injury, where we sought in vain for guidance on the treatment of cerebral œdema or, better still, its prevention by such measures as early depletion therapy. Many pertinent questions are asked and answered, e.g., can concussion represent more than a momentary loss of consciousness and it is it an essentially transient state, as was defined by Wilfred Trotter, or may it last for hours or longer? The author believes it can be prolonged.

On the question of the relationship between concussion contusion, and compression, the view is advanced that brain 'fling' causes concussion as a general effect, but if the fling causes a particular area of the brain to impinge on one of the bony irregularities of the interior of the skull, a local effect in the form of a contusion is then produced. The phenomena of the post-concussional state, such as headache, dizziness, and confusion are held to be due to impairment of the vasomotor control of the vessels of the brain and its coverings so that there is an inability to make adjustments for quickly changing situations. In a discussion on the mechanism of concussion, the hypothesis of traumatic anæmia held by Von Bergmann, Kocher, Trotter, and others is dismissed and concussion is defined as "a direct effect of violence on the nerve cells of the brain resulting in temporary depression or cessation of cerebral function without immediate detectable evidence of structural change in the cells", but does this really take us much farther than did Astley Cooper in 1829, who defined concussion simply as "a shock which the brain has received"? There is much that is thought-provoking in this book which will have a wider appeal than to neurologists alone, and the surgeon who has to cope with head injuries will find much here on which to ponder.

BOOK NOTICES

[The Editorial Committee acknowledge with thanks the receipt of the following volumes. A selection will be made from these for review, precedence being given to new books and to those having the greatest interest to our readers.]

Ratna Hirurgija. Edited by B. BRECELJ, D. DIMKOVIĆ, B. GUŠIC, L. KRALJ, B. LAVRIČ, G. NIKOLIS, K. OBERŠLIK, I. PAPO, A. TELEBAKOVIĆ, and A. ŽUPANČIČ. 6¾ × 9¼ in. Volume I. Pp. 610, with 274 illustrations, some coloured. 1953. Belgrade: Izdanje Sanitetske Uprave Jra.

Die Lungenmesektionen. By PROF. DR. A. LEZIUS, Hamburg. With a Foreword by PROF. DR. R. NISSEN, Basel. 7¾ × 11 in. Pp. 143 + viii, with 112 illustrations. 1953. Stuttgart: Georg Thieme. DM. 49.80.

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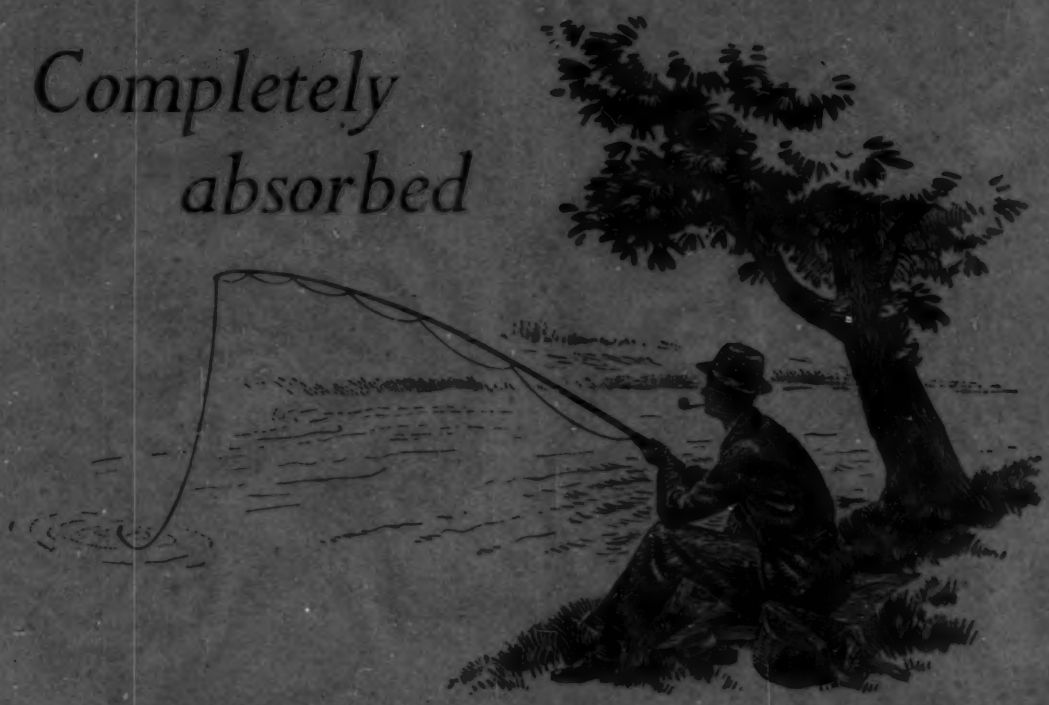

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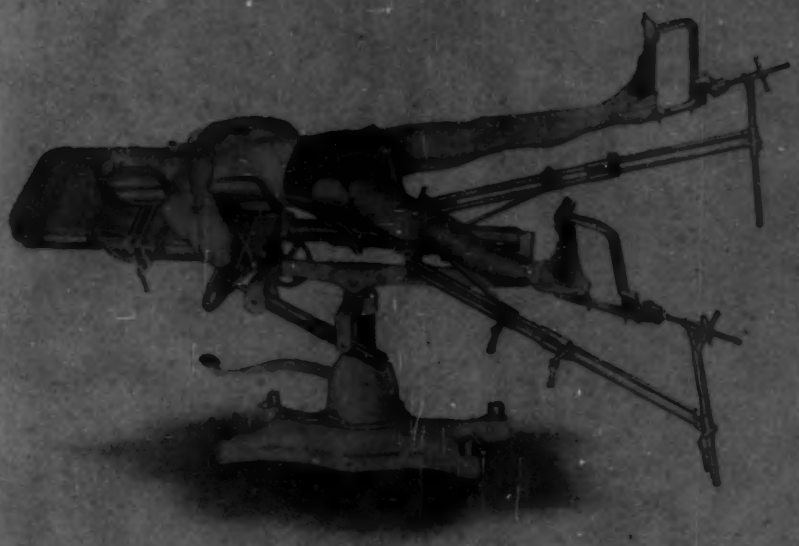

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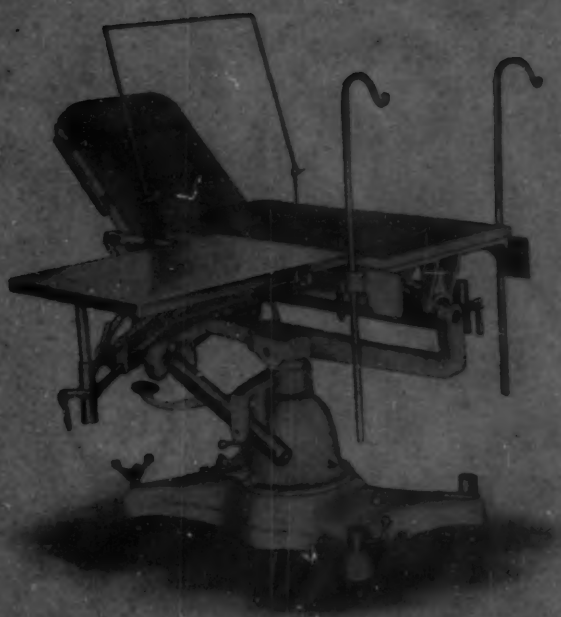

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